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Greeting

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S. A. E. JOURNAL

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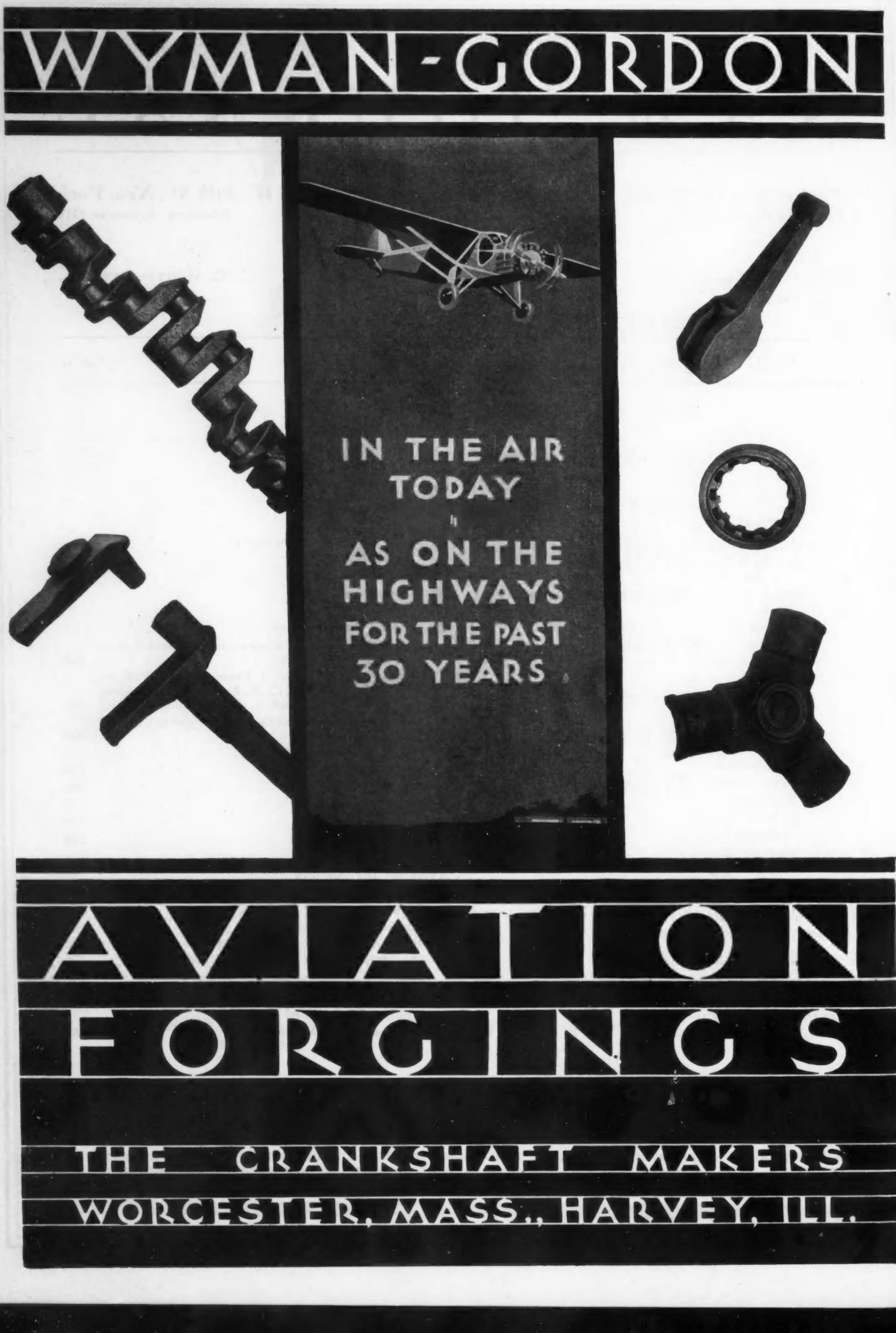
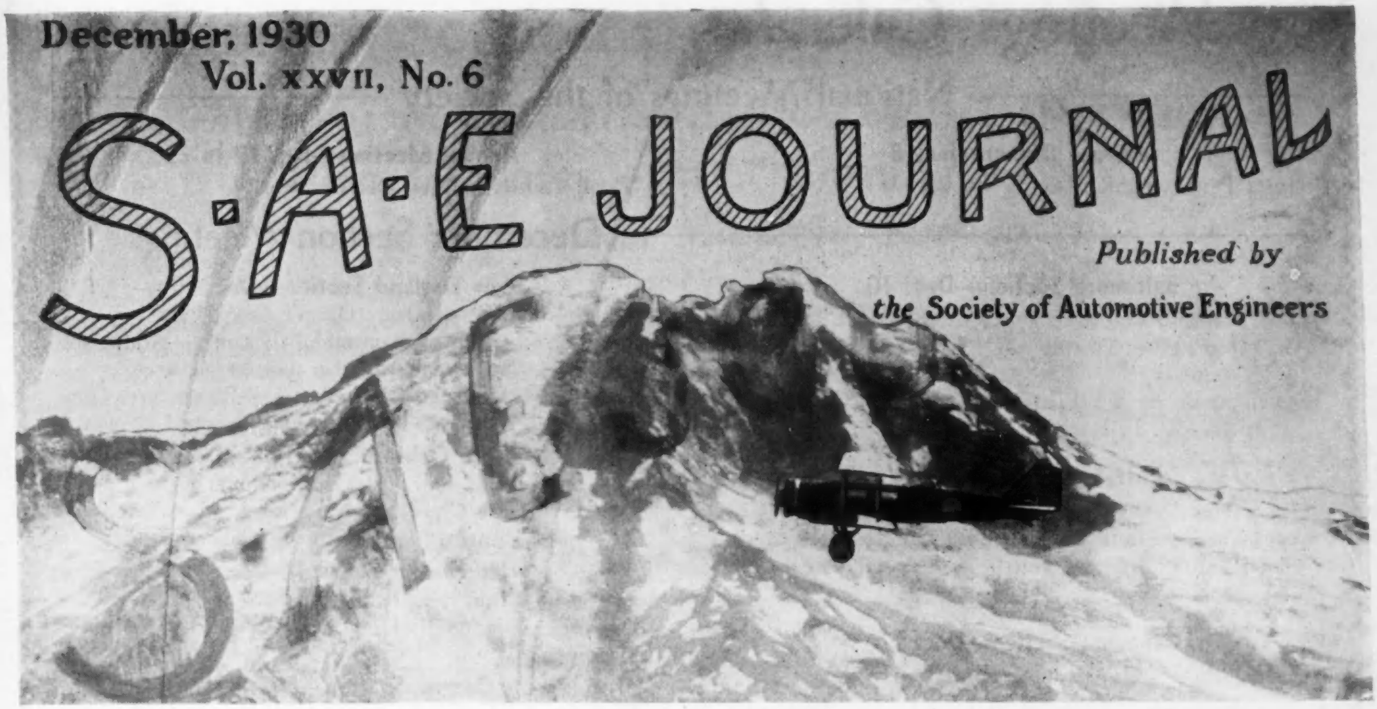

WYMAN-GORDON
IN THE AIR TODAY AS ON THE HIGHWAYS FOR THE PAST 30 YEARS
AVIATION FORGINGS
THE CRANKSHAFT MAKERS
WORCESTER, MASS., HARVEY, ILL.



Rockne and Kettering at Annual Dinner

KNUTE K. ROCKNE will be the speaker at the Annual Dinner, to be held at Hotel Pennsylvania, New York City, on the evening of Thursday, Jan. 8. Although Mr. Rockne's official position is that of football coach in an institution well and widely known throughout the Country for its gridiron victories, the breadth of his experience and the extent of his contacts are of such magnitude that his mastery of football is but one item among many that combine to make him recognized as a leader of men. Members of the Society who have heard him will be overjoyed to hear him again, and those who have not had that pleasure can look forward with eager anticipation to the opportunity to listen to the philosophy, both penetrative and friendly, of this careful student of world affairs, man of genial personality, writer of note and speaker of great distinction.

Charles F. Kettering has consented to be the toastmaster of the occasion, and this announcement alone should be sufficient to fill the ballroom of the Hotel Pennsylvania on the evening of Jan. 8. When one considers the great number of members who would "rather hear Ket than eat" and reflects that the dinner furnishes an opportunity to do both, he will realize that the success of the 1931 Annual Dinner is, with the making of this announcement, already assured.

James Schermerhorn, of Detroit, with whose happy graces as a speaker many members are already pleasantly familiar, will be the official humorist.

Arrangements for the Dinner are under the direction of the Annual Dinner Committee, composed of W. T. Fishleigh, chairman; F. K. Glynn and B. J. Lemon. This Committee is to be congratulated upon the splendid program it has prepared.

A Five-Day Annual Meeting

The pages of the calendar are inevitably turning toward the dates of the 1931 S.A.E. Annual Meeting, which will open on Jan. 19 and close on the 23rd. As has been the custom for many years, the meeting will be held in Detroit, at the Book-Cadillac Hotel. All eight of the Society's Professional Activities Committees have had a share in arranging the program, and each Activity will be the sponsor of one or more technical sessions. In addition, the Standards Committee and the Research Committee will each sponsor one session.

One of the most interesting sessions of the entire meeting will feature an address by Robbins B. Stoeckel, State Commissioner of Motor Vehicles for Connecticut. Commissioner Stoeckel will discuss an important phase of that superlatively important subject, the problem of safety.

Engine and Chassis Sessions

The Engine Session will include a paper on Air-Cooled Engines for Motor-Cars, by E. S. Marks and C. T. Doman of the H. H. Franklin Mfg. Co., and a paper on Torsional-Vibration Dampers, by J. P. DenHartog and J. G. Baker, of the Westinghouse Electric & Mfg. Co.

Oil Coolers and Oil Cooling is one topic to be considered at the Fuels and Lubricants Session; L. P. Saunders, of the Harrison Radiator Corp., will present a paper on this subject. The other paper scheduled for this session is by R. T. Haslam, of the Standard Oil Co. of New Jersey, on The Properties of Fuels and Lubricants Made by the Hydrogenation Process.

The Detonation Session will be in the nature of a symposium at which papers will be presented by the following authors: D. P. Barnard, of the Standard Oil Co. of Indiana; D. B. Brooks, N. R. White and G. C. Rodgers, of the Bureau of Standards; J. M. Campbell, W. G. Lovell and T. A. Boyd, of General Motors Corp. Research Laboratories; Graham Edgar, of the Ethyl Gasoline Corp.; and H. F. Huf, J. R. Sabina and J. B. Hill, of the Atlantic Refining Co.

At the Chassis Session, B. J. Lemon, of the United States Rubber Co., will discuss Tires for Drop-Center Rims, R. K. Lee, of the Chrysler Corp., will talk on New Uses for Rubber on Cars, and C. S. Ash, of the Kelsey Hayes Wheel Corp., on the Trend in Drop-Center-Rim Construction.

(*Concluded on p.* 731)

Meetings Calendar

National Meetings of the Society

Annual Dinner—Jan. 8
Hotel Pennsylvania, New York City

Annual Meeting—Jan. 19 to 23
Book-Cadillac Hotel, Detroit

December Section Meetings

Baltimore Section—Dec. 10
Lord Baltimore Hotel; Dinner 6:30 P.M.
Aircraft-Engine Testing—B. T. Neill, Bureau of Standards
Development in Fuel Injection in Two-Cycle Engines—W. B. Robe

Buffalo Section—Dec. 3
Statler Hotel; Dinner 6:30 P.M.
Corrosion-Resistant Steels, Their Properties and Uses—Dr. John A. Matthews, Crucible Steel Co. of America.

Canadian Section—Dec. 17
Royal York Hotel, Toronto; Dinner 6:30 P.M.

Chicago Section—Dec. 8
City Club; Joint Meeting with the Chicago Chapter of the American Society of Steel Treaters
Practical Application of Stainless Iron and Steel—Jerome Strauss, Chief Engineer, Vanadium Corp. of America

Cleveland Section—Dec. 15
Hotel Statler; Dinner 6:30 P.M.
Mental Gears of Engineers—Prof. Yale S. Nathanson, University of Pennsylvania

Detroit Section—Dec. 8
Book-Cadillac Hotel; Body Meeting
Technical Session 5:15 P.M.—Highlights of the Paris Salon—Amos Northup, Murray Corp. of America
Dinner 6:30 P.M.; Entertainment
Technical Session 8:00 P.M.—Foreign Car Bodies—E. V. Rippingille, General Motors Corp.

Indiana Section—Dec. 18
Hotel Severin, Indianapolis
Speed and Power Losses of Motor-Vehicles Caused by Wind Resistance—Prof. H. M. Jacklin, Purdue University, and Louis Schwitzer, Schwitzer-Cummins Co.

Metropolitan Section—Dec. 10
A. W. A. Clubhouse, 357 W. 57th St., New York City; Dinner 6:30 P.M.
Aircraft Radio—Paul Goldsborough, Vice-President, Aeronautical Radio, Inc.
Radio Corporation of America and Western Electric Demonstrations; Wright Engine Exhibit

Milwaukee Section—Dec. 3
Milwaukee Athletic Club; Dinner 6:30 P.M.
The Commercial Side of Research—Meade F. Moore, Chief Engineer, Nash Motors Co.

New England Section—Dec. 10
Hotel Kenmore, Boston; Dinner 6:45 P.M.
Mass Production of Automobile Frames—Addresses by several speakers; also motion pictures
Recently Introduced Methods of Temperature Control—Addresses by several speakers

Northern California Section—Dec. 11
Engineers Club, San Francisco; Dinner 6:30 P.M.
One, Two and Three-Stage Springs—M. Martensen, Sales Manager, Laher Spring Co.

Northwest Section—Dec. 5
Engineers Club, Seattle, Wash.; Dinner 6:30 P.M.
Dynamic Balancing—H. O. Hanawalt, Engineering Specialty Co.

Oregon Section—Dec. 12
Multnomah Hotel; Dinner 6:30 P.M.
Motorbus Engine Operations and Maintenance—By an Engineer from the Hall-Scott Motor Car Co.

Philadelphia Section—Dec. 10
Philadelphia Automobile Trade Association, 715 North Broad Street; Dinner 6:30 P.M.; Entertainment
Automotive Patents—J. H. Hunt, Patent Department, General Motors Corp.

Pittsburgh Section—Dec. 11
Pittsburgh Athletic Club; Dinner 6:30 P.M.

Southern California Section—Dec. 11
City Club, Los Angeles; Dinner 6:30 P.M.
Bearings and Bearing Loads—Ethelbert Favary, Moreland Motor Truck Co., and others; also a surprise speaker

St. Louis Section—Dec. 9
Engineers Club, 4359 Lindell Boulevard; 8:00 P.M.
Problems Connected with the Manufacture and Servicing of Automobiles—C. D. Smith, Development Department, Firestone Tire & Rubber Co.

Syracuse Section—Dec. 2
Hotel Syracuse, 7:45 P.M.; Buffet Supper after meeting
American Gearsets for Passenger Cars—Herbert Chase, Associate Editor, *Product Engineering* and *American Machinist*

Washington Section—Dec. 10
Washington Hotel; Dinner 6:30 P.M.; Entertainment
Past, Present and Future of Piston Rings—A. Preston Petre, American Hammered Piston Ring Co.
The General Problem of Airship Transportation—Dr. Karl Arnstein, Goodyear Zeppelin Corp.; also motion pictures

Wichita Section—Dec. 6
Airplane trip to Spartan Aircraft Co. plant at Tulsa, Okla.
Management of an Engineering Department—Rex Beisel, Chief Engineer, Spartan Aircraft Co.

Chicago Section Hears Two Addresses

Improvement in Industrial-Engine Design Described by Allen C. Staley—H. L. Horning Tells of Observations Made in Europe

DIESEL engines are now competing with gasoline engines in the industrial field, but, because of the higher first cost of the former, they must operate over a high percentage of days in the year to return the capital outlay through the more economical operation. This is the import of a statement made by Allen C. Staley, of the Climax Mfg. Co., in the course of an address on The Internal-Combustion Engine in the Industrial Field, given at the Nov. 6 meeting of the Chicago Section.

At the same meeting Harry L. Horning, of the Waukesha Motor Co., recounted some observations on European industrial progress which he made on a recent trip abroad. While some European countries are lagging four or five years behind the United States in internal-combustion engineering practice, he said, the practices now followed in Europe undoubtedly will be supplanted in the future by more advanced practices.

Mr. Horning pinch-hit at this meeting for the second time in the month, as he said, having substituted also at the Milwaukee Section meeting. Besides giving an interesting and informative address, he presided as Chairman of the technical session following a brief business meeting.

Section and National Committeemen Chosen

This second autumn meeting of the Chicago Section was as well attended as the first one, well over 100 members and guests being present at the dinner and the technical session. The dinner started promptly at 6.30 p. m., and while the courses were being served some very pleasing entertainment was furnished. Chauncey Parsons, star in Night in Venice and in Gay Paree was very well received. Considerable merriment was noticeable during the performance of Simmons and Clifford, two misses who have performed on the radio and whose acting is as clever as their singing.

The business meeting was presided over by Section Chairman E. W. Stewart, who spoke briefly on the need for aeronautic activity in the Section, saying that he had noticed an increased interest in the work of this nature and believes aeronautic activity will be welcomed by many of its members. E. A. Sipp was appointed Chairman of the Aeronautic Division of the Section.

D. E. Gamble, of Borg & Beck, was elected as the Section's representative on the Nominating Committee for the nomination of officers of the Society for 1931; and John Erskine, research engineer of the International Harvester Co., was elected to the Sections Committee of the Society for next year.

Mr. Stewart then introduced Mr. Horning who took the chair and introduced Mr. Staley.

How Engine Problems Were Solved

In his paper Mr. Staley pointed out many of the problems encountered in the industrial-engine field and told what his company has done to solve them. An analysis was first made to show the types and sizes of engine needed. The expense of the analysis, he said, was charged off over a period of years. The address was illustrated with slides showing the redesign of the manifold, cylinder-head and engine block, which was necessary to bring performance in the industrial field to the desired level. This research and redesign work resulted in the development of the Climax U-41 engine, which operated with a noticeable decrease in fuel consumption and increase in power. Thus, improved practice and design brought into being a complete new line of engines which are called Blue Streak. A six-cylinder engine was later developed which bettered in performance the Blue Streak engines because of improved turbulence, reduced flame travel and uniform cooling throughout.

Power requirements in the industrial field are governed somewhat by the practice in effect before the arrival of the gasoline engine in work of this kind, said Mr. Staley. The internal-combustion engine replaced the steam engine to a marked extent. The engines had to be designed for maximum efficiency and economy. Numerous experiments on spark timing showed a marked effect in reducing the fuel consumption.

With reference to the Diesel engine, the speaker stated that it has been shown that many factors should be taken into consideration when either a Diesel or a gasoline unit is to be purchased. One of these factors is first cost, which is heavy in the Diesel-type engine.

At the conclusion of Mr. Staley's paper numerous questions were asked and answers were given by the author.

Mr. Horning then spoke extemporaneously on his Impressions of a Recent European Trip. His first observation was that European civilization is measured by the tools used. In Austria he saw the harvest being reaped with a scythe. While Great Britain and France have some tractors, the number is very small as compared with those in the United States. In Italy one seldom sees a plow being pulled by horses, most of them being drawn by oxen, and crude wooden plows are drawn by oxen in Spain. Lawns about the homes in Germany are mowed with sickles. It is obvious that a great gap separates Europe and the United States in many of the practices followed.

Motor-cars and trucks are used extensively in Europe, according to Mr. Horning, who remarked that the races are merging in the matters of dress and style. A real melting pot similar to that of some time ago in this country is developing.

Many American industrial machines are used in European factories, but there are no American workmen and the work is done in a leisurely way. As a result, production suffers. Russia is estimated to be only one-quarter to one-third as efficient industrially as the United States. Germany is making greater strides in this direction and gives promise of occupying a front rank among the European nations.

Backward in Heavy-Duty Engines

A striking fact noticed by Mr. Horning is the European lack of knowledge as to what constitutes a heavy-duty engine. The engines are not subjected to maximum-load operation, but excellent care is given them and they are well lubricated and cleaned. Service rendered is of a very high standard.

In respect to design, the European heavy-duty engines are four or five years behind those in the United States. The crankshafts are very frail and exhaust-valve cooling is not considered as it is in this Country. This is due to the fact that the engines are not required to do sustained heavy work, the service being not nearly so severe as that given our own heavy-duty engines. Manifold design is poor, the manifolds being very large, which results in lack of smoothness in operation.

Truck engines do not idle well, according to Mr. Horning; in fact, very little slow-speed running is done. The engines are either kept running at high speed or are shut off entirely, as to idle the average European engine would be ruinous to it.

Perhaps the greatest engine problem in Europe is cylinder wear. The engineers are just finding out about air-cleaners, in which respect they are lagging behind as compared with the development in this Country.

Automotive Diesel-Engine Progress

Greater progress is being made in Europe in automotive Diesel-type engines, particularly since 1927, and these engines are giving good service. The popularity of the type is no doubt due in a large measure to the fact that gasoline sells for approximately 40 cents per gallon throughout Europe and the problem of the engineers is to develop a kind of an engine that will use heavy fuel.

Diesel-engine fuel in Germany has properties that are very different from those of the average Diesel fuel in the United States. It is very greasy and has noticeable body, having lubricating qualities that make for long life of the plungers. The problem of plunger wear confronted by engineers here is not met abroad.

In concluding his talk, Mr. Horning remarked that many of the engineering practices now followed in Europe undoubtedly will be supplanted in the future by more approved practices. The principal reason for the slow development of heavy-duty engines there is primarily the European closed mind. Many Continental companies building engines are using accessories that are very inefficient, instead of buying the more efficient accessories that are available and thus tacitly admitting that someone else can build accessories or automobile parts which are superior to those they can build. European industrial progress can be speeded up if something can be done to relieve this very noticeable condition.

Successful Bus Operation

St. Louis Section Told of Operating and Maintenance Methods of Local Company

HOW motorcoach service of the People's Motorbus Co. in St. Louis has developed in seven years from a fleet of 17 to one of 193 vehicles, and the maintenance method that has resulted in elimination of a large percentage of failures on the road, were described at the Nov. 4 meeting of the St. Louis Section by Joseph Conniff, general manager of the company. Mr. Conniff spoke with the authority of thorough knowledge of motorcoach maintenance, as before coming to the United States he was engaged in the manufacture of motor omnibuses in England, then was identified with the Fifth Avenue Coach Co. in New York City and, after several years of service in St. Louis, was recently made general manager of the People's company.

The meeting was held at the Engineers' Club of St. Louis. After the preliminary business of reading the minutes of the October meeting, W. L. Dempsey, Section Chairman, was elected to represent the Section on the Nominating Committee of the Society and G. P. Dorris was elected to represent it on the Sections Committee. Both men have long been connected with the automobile industry, the connection of Mr. Dorris going back to the "horseless carriage" days, and both were largely instrumental in promoting the establishment of the St. Louis Section.

Changes in Vehicles Used

Summarizing the operations of the company he represents, Mr. Conniff stated that the People's Motorbus Co. started in 1923 with 17 55-passenger double-deck buses operating over a 10-mile route and now operates 193 double and single-deck buses over routes aggregating 73 miles. In this seven-year period these buses have covered a total of 41,500,000 miles. In 1929 the fleet made an aggregate of 7,250,000 miles and consumed 1,500,000 gal. of gasoline, 5000 gal. of 600-W cylinder oil and 26,000 gal. of lubricating oil. The speaker remarked, in this connection, that, although the company's vehicles operate only on city streets, except when specially chartered for outside runs, the State exacts a tax on all the gasoline consumed for maintenance of the State highways.

The company has built 15 73-passenger buses on old chassis and powered these with six-cylinder engines. Other important work includes changing the old four-cylinder sleeve-valve engines to poppet-valve engines, not because of a preference for poppet valves, but to increase the horsepower. This required a new cylinder-block, new camshaft, larger radiator, replacement of the thermosiphon cooling system by a water-pump system, and brought unforeseen difficulties. However, some 60 of the old vehicles have been converted, and their operation is now very satisfactory. The additional horsepower was needed to maintain the normal operating speed of 10¾ m.p.h. with double-decked buses.

One difficulty that the company has not been able to overcome is the escape of obnoxious gas from the exhaust. This, said Mr. Conniff, is a problem that merits the serious attention of the engineering fraternity and remains as probably the most difficult obstacle to overcome in the operation of automobiles.

Inspection and Service System

The maintenance system of this company depends on (*a*) drivers' daily reports, (*b*) general inspection at 3000-mile intervals and (*c*) overhaul at 12-month periods. The driver reports at the end of each run the operating condition of the bus, and it is the duty of the garage force to check the items so listed. In addition, the bus is examined for other defects, axle housings are checked nightly, and transmissions, compressors, rear universal-joints on the single-deck buses and other parts are checked weekly.

After 3000 miles of operation the bus is taken to a secondary garage, where inspection will perhaps reveal a worn transmission that requires replacement. At this garage the ailing unit will be taken out and a serviceable one installed. The worn transmission will be sent to the major-overhaul garage for repair and return to stock.

All service operations, excepting those undertaken at the major service garage, can be completed in the normal day of from 6 a. m. to 4 or 5 p. m., at which time the bus is expected to be on the road to take care of the peak load. Garage employees are penalized for failure to comply with the time requirements. At the major-overhaul garages worn components are repaired as routine business. Every 12 months or thereabouts the buses are brought in for a general overhaul, including removal of the body for repair and relacquering. The body condition is the basis for determining whether a bus needs overhauling. The chassis is washed and all components are removed, inspected and replaced with other units if necessary.

Road Failures and Upkeep Reduced

As a result of the routine methods established, the company has been able to eliminate a large percentage of failures on the road and excessive maintenance. It boasts of only 11 broken crankshafts in 41,500,000 miles of operation.

The company is extremely careful of its good reputation and exercises great care in the selection of its conductors, who ultimately become drivers, accepting only men of high intelligence, good physical and moral background, and of certain statures. Since the cost of accidents, excessive maintenance and other items due to careless drivers is high, the care that is exercised in choosing employes has reduced these items of operating cost and served to protect the good-will of the public.

Current American Transmissions

New England Section Hears Herbert Chase Describe and Comment on Them

EASE of gearshifting and quiet operation are at least two respects in which automotive engineers apparently are agreed that conventional transmission design was in need of improvement, Herbert Chase, associate editor of *Product Engineering* and the *American Machinist*, told members and guests of the New England Section at its meeting in the Hotel Kenmore, Boston, on Nov. 5. The speaker presented the paper entitled, Comment on American Passenger-Car Gearsets, which he gave at the Semi-Annual meeting of the Society last May. [This was published in the S.A.E. JOURNAL for June, beginning on p. 727.—Ed.] Mr. Chase supplemented the paper with a description of the free-wheeling transmission introduced this autumn by the Studebaker Corp. [A paper by D. G. Roos and W. S. James, entitled Free-Wheeling, presented at the Metropolitan Section meeting is to be published in the January issue of THE JOURNAL.—Ed.]

Forty officers and other members of the Section and its guests attended a dinner that preceded the technical session, and 70 more came in after the dinner to hear Mr. Chase. Section Chairman Albert Lodge presided.

Free-Wheeling Discussed

After illustrating, describing and commenting upon current American unconventional three and four-speed transmissions, Mr. Chase presented a slide of the new free-wheeling transmission and spoke briefly about it. When he finished, interest immediately centered in discussion on this device and operation of the car with it. The first question related to the sets of four rollers used in it, John F. Smith asking how a piece of machinery can be machined so that the four rollers grip uniformly and why single rollers should not be used instead. In reply, Mr. Chase quoted D. G. Roos as saying that, although it is theoretically impossible to obtain perfect bearing on all four rollers, the company had succeeded in eliminating all "bugs" and produced an improved roller-clutch. M. R. Wolfard, of Hopewell Brothers, suggested that four rollers were used to produce a clutch that will stand up and wear well and that eventually all the rollers are brought into play successively, not simultaneously.

Question of the danger of an accident when free-wheeling down hill was raised by Mr. Barkley and brought from Mr. Chase the response that it would not be difficult to engage a positive gear and that, although an inexperienced driver might let the car get out of control and be wrecked, this can happen with any car. He added that braking today is 100 per cent more effective than it was several years ago, so there is not the same danger when coasting. H. L. Fallows, of the Studebaker Sales Co. of Boston, said that he had driven a free-wheeling car down the Mount Washington road, with its exceptionally steep grades and hairpin turns, at 40 m.p.h. and at no time did he have a feeling of danger or insecurity. Later in the discussion he remarked that the only bother he had encountered with free-wheeling was due to cold weather causing a little slipping, but this was easily remedied by the application of a few drops of kerosene.

Other Types Considered

A few questions were asked regarding hydraulic transmissions but these were dismissed with the thought that, while they are very good, they are too complex and expensive.

Discussion then turned to four-speed transmissions, F. E. H. Johnson, of the Noyes-Buick Co., of Boston, asking if there seems to be a tendency away from this type rather than an increase in the number of car makers adopting it. Although he had not gathered any statistics since preparing his paper last spring, said Mr. Chase, his impression is that the tendency now seems stationary. Mr. Johnson then inquired if the reason for adopting four speeds was to keep down the engine speed or because it was cheaper to put a four-speed transmission in the car than to balance the engine. Mr. Chase answered that the point was debatable and agreed with Mr. Johnson that the public wants better results without having to learn to use four speeds; drivers would prefer noise to bothering to shift gears more frequently.

National Committee Members Chosen

The meeting elected W. R. Wolfard to represent the Section on the Nominating Committee of the Society and Glen Whitham to represent it on the Sections Committee. Chairman Albert Lodge was elected as alternate on both committees.

At the December meeting, which is scheduled for the 10th of the month, a representative of the A. O. Smith Co. is to show motion pictures of automatic progressive quantity production of automobile frames.

Air-Transport and Lubrication

Paul Collins and George Round Give Washington Section Information on Two Topics

TURKEY dinner in the Spanish room of the Washington Hotel, soft light filtering through the glass ceiling, an arena formed by a rectangular table with about 75 guests facing in. The turkey gone, came the salad, and with it a sweet-voiced songstress to grace the arena and croon songs. Came another with a violin, who played and stepped lively the while. Came yet another, and so began an evening for the Nov. 13 meeting of the Washington Section, with the avowed purpose of learning of air transportation from Paul F. Collins, vice-president of the Washington, Philadelphia, New York Air Line, and about oil from George A. Round, of the Vacuum Oil Co.

Dr. H. C. Dickinson, chief of the heat and power division of the Bureau of Standards, opened the meeting after dinner, with about 125 members and guests then present. Dr. Dickinson is the designer of the engine altitude chamber at the Bureau for simulating altitude conditions on the ground. He is also father of the friction and lubrication section at the Bureau.

Pioneering in this lightest of all transportation mediums, the air, began with the Wright brothers, Dr. Dickinson said. Then came Curtiss, who flew down the Hudson. An English Channel flight was made. Then came the pioneers of the war, who rode through the sky to fame or death. The NC boats flew the Atlantic, and then, alone and unheralded, Colonel Lindbergh emblazoned his name in the everlasting halls of fame and in the hearts of all the civilized world.

So came the impetus for our present start in commercial aviation. The pioneers at present are the commercial companies which are introducing the joys and thrills of flying to the public. With these preliminary remarks, Dr. Dickinson turned the meeting over to Mr. Collins.

Commercial Aviation Problems

The problems of commercial aviation, Mr. Collins said, are similar to those of any other business undertaking. The business must be operated to return a net profit. Such an undertaking involves the selection of terminals and terminal facilities, planning the length of the route, the selection of airplanes, and other considerations.

Preliminary planning should include a study of the ground traffic in the territory over which the planes are to be operated. An air-passenger service usually expects to get about 2 per cent of the rail traffic, counting out the natural cancellations due to weather.

The railroads have created a standard of comfort and service in travel with which all other forms of transportation must compete. This makes it necessary to provide for the passengers and give them the service to which they are accustomed. Engine noise, air sickness, and uneasiness of mind are the chief offenders to comfort. The first will probably be more or less eliminated as engines and mufflers are improved, and passengers will get over the uneasy feeling. Airsickness, which afflicts about 6 per cent of the passengers, is a problem that still seems to lack a solution.

About 3,000,000 miles per fatal accident was last year's record for commercial companies, as against 350,000 miles for promiscuous flying. This gives the commercial companies a 9:1 preference over promiscuous flying, which Mr. Collins attributed largely to the helpful regulations of the Department of Commerce and the Department's efforts to determine the causes of accidents and to eliminate them wherever possible.

Passenger rates are an important consideration in determining the number of passengers who will travel by air in preference to the ground. Mr. Collins feels that, to attract many passengers, the air rates must be comparable with ground rates. But flying is cleaner than ground travel, and time-saving is the deciding factor with many passengers.

Airplane Type and Equipment

The choice of airplanes is very important, Mr. Collins continued. Depreciation is not considered as important as their being made obsolescent by new developments that are continually being made. Multi-engined planes he regards as essential; the Stinson planes that his airline is using will climb to 6000 ft. on any two engines with a full load.

Engine starters are regarded as essential to cut down the ground crew and facilitate taxiing on the ground. Each engine is equipped with a direct-drive starter similar to an automobile starter. All the starters in a plane are operated from one battery, which is charged each night in the hangar, thus avoiding carrying a generator.

Heating is somewhat of a problem but patent applications have been filed by the company on a new type of heater using liquid in a tube to collect heat at high temperatures from the exhaust system and carry it to the cabin. The lubricating oil is warmed by immersion heaters before the engine is started, to reduce the warming-up period.

Oil Properties and Tests

The engineering department, began Mr. Round, is not responsible for the advertising and the salesmen of an oil company, and he seemed glad to get the statement out of his system.

Before Mr. Round got under way with his own address, he expressed confidence in Mr. Collins's airline and said he believes a factor in airsickness that is little considered is that when flying it is impossible to see the bumps and so be psychologically prepared for them, as when riding on the ground.

Oil has been the life-blood of all the engines from Watt's down to the millions now in use. It must perform various functions in an engine, continued Mr. Round. It must form a seal for the piston, carry away heat, and emulsify easily, but it must not oxidize, carbonize or gum to any great extent.

The speaker then explained with the use of slides some of the tests used to determine and measure the values of the various properties of oil. Most of the characteristics are impossible to determine by any easy tests, which makes it impossible for the filling-station buyer to judge the quality of the oil he buys except perhaps from experience. Viscosity or body, oiliness, gumming tendencies, oxidation rate, carbonizing tendencies and consistency at low temperatures are the chief factors governing oil performance.

One problem mentioned is that of preventing scoring of gear teeth under very heavy duty. A deficiency of oiliness under these conditions tends to cause abrasion and scoring. Sulphur in the oil helps to prevent this, said Mr. Round, especially when the loads are above 8000 or 10,000 lb. per sq. in. Dirt in an oil affects the wear of parts more than the difference in lubricants.

The gumming tendency of an oil has no simple test, as far as Mr. Round knows. The usual test used by his company is to run the oil for 100 hr. under service conditions.

Oxidation, or the turning black of an oil, varies with different lubricants and is not especially harmful. No good test for this property is used except that of running the oil under service conditions. Some dark oils may conceal foreign material, which is usually not abrasive but has a tendency to clog the oil lines. Photomicrographs taken with light of different colors are used for detecting various impurities. Sand particles or abrasives are brought out by the use of polarized light.

Evaporation, which usually affects the oil consumption, is another factor that is difficult to judge and requires long periods of test under service conditions. In fact, the only real tests for most of the important properties of the oil, aside from the viscosity, are those of actual service conditions. Mr. Round confessed that the engineering department does not known all about oil, in spite of anything the advertisements may say.

Discussion followed the close of the talk. Mr. W. H. Herschel and Dr. M. D. Hersey, both of the Bureau of Standards, told of some of the work being done at the Bureau, where tests under service conditions are carried on in much the same way as the work spoken of by Mr. Round. A. W. Herrington, designer of the Coleman four-wheel-drive truck and now building the Herrington truck, also took an active part in the discussion.

Among those present at the meeting were Dr. George A. Lewis, of the National Advisory Committee for Aeronautics; Lieut. L. D. Webb, of the Navy Department; and Major R. C. Williams, U. S. A., with a party from Fort Meade.

A motion picture entitled, The Story of the Automobile Engine, was shown after the discussion.

Comment on Modern Gearsets

Philadelphia Section Hears Chase's Views on Three and Four-Speed Types

GEARSETS, Futuristic and Otherwise, really was not the subject of Herbert Chase's Semi-Annual meeting paper which the author presented to some 60 members and guests of the Philadelphia Section at its Nov. 12 meeting, but the paper and the resulting discussion engendered the mental question whether the most modern of transmissions, the somewhat complicated internal-gear four-speed transmission, will enter the same decline in favor that is so freely predicted for the so-called futuristic in art.

Speaking of the four-speed transmission, Mr. Chase pointed out that one of the major advantages claimed for it is the lower axle-ratio that it permits and which provides lower engine-speeds at high car-speeds, with lessened wear on engine and possibly upon passengers. With this low over-all ratio in direct or fourth speed, the quiet third speed is relied upon to provide the rapid acceleration that the American driver demands. This, however, is predicated upon his willingness to shift from fourth to third speed to obtain this desirable traffic performance. That this willingness is not universally evidenced is indicated by the fact that some manufacturers, who originally

lowered the rear-axle ratio when the four-speed transmission was adopted, have again raised it to virtually the same figure used with the previous three-speed transmission, at the same time retaining the four-speed design.

Apparently the aversion to gear-shifting is rather deeply ingrained in the American driver's mind and as a result he demands his performance "in high." If he does not get it, the car is designated as sluggish, regardless of the fact that he has a quiet third speed which will give him the desired performance.

A second school of thought, which can be termed that of the three-speed advocate, believes that better all-round performance can be obtained by the combination of a low rear-axle ratio and a larger engine with the simpler three-speed transmission. This provides the desirable lower engine-speed at high car-speed, and the larger engine supplies sufficient power to give acceptable low car-speed performance, both desiderata being obtained without the necessity of shifting.

Three-Speed Sets Being Improved

This position is not allowed to go without challenge, however, and one criticism is the greater weight and cost of the larger engine. It is rather interesting to note, pointed out Mr. Chase, that the two outstanding manufacturers in the low-price light-car field, the Ford and the Chevrolet companies, use relatively large engines and low axle-ratios, and this without undue sacrifice of either performance or light weight. Certainly the lower cost of the simpler three-speed transmission goes some distance in reducing the apparent increase in cost of the larger engine. Likewise, the greater cost and complexity of the internal-gear four-speed transmission, both as regards manufacture and service, is somewhat of a detriment to its universal use.

When the internal-drive third speed made its appearance it marked an advance in design that permitted quiet and easy shifting from direct drive to the next lower transmission speed, and also quieter operation in that speed. However, progress has been made with other types of drive, and the quietness of the internal-gear design is being challenged by designs employing specially ground spur teeth, herringbone gears and helical gears. These are usually constant mesh, with dog-clutch engagement, and have been incorporated in both three and four-speed designs. Ease of shifting is being improved by special design such as is employed in the syncromesh transmission.

Free-Wheeling Raises Conjecture

The newest thing in transmissions, free-wheeling, was also discussed. This consisted mainly of questions and conjecture, the design being still too new to have proved itself in the hands of many car owners. The points raised included the manufacturing difficulties of the roller clutches; the extreme nicety of fit required if all the rollers are to bear their share of the driving load and their ability to withstand wear; and the disconcerting reaction of the driver who feels what seems to him as almost an acceleration when he lifts his foot from the throttle, so accustomed has he become to the immediate braking effect of the engine with the ordinary transmission. Answers to these and other questions will be available when the chief inspector of all things automotive, the American public, has completed his final test.

Traffic Engineers a Crying Need

Speakers Tell Indiana Section that Traffic Control Methods Are Out of Date

AUTOMOBILE engineers are responsible for highway traffic congestion that is resulting in an increasing number of fatalities per 100,000 vehicles, but they have done everything possible to make motor-vehicles safe to operate. Now we need the best efforts of highway, city-planning and traffic engineers to reduce the hazards and better traffic-control systems and devices.

This is the gist of two papers and discussion of them presented at the traffic-control meeting held by the Indiana Section on Nov. 13 at the Atheneum in Indianapolis following a get-together dinner. The subject brought out more than 150 Section members, their friends, public officials and others interested in highway safety and traffic control.

Section Chairman Louis Schwitzer, who presided, called a brief business meeting following the dinner, and George H. Freers, chief engineer of the Marmon Motor Car Co., was elected to serve on the Nominating Committee of the Society, and Charles A. Merz, president of the Merz Engineering Co., was elected a member of the Sections Committee to represent the Indiana Section in the National body.

Chairman Schwitzer announced that at least two papers are to be presented at the Dec. 11 meeting, one by Prof. H. M. Jacklin, of Purdue University, on Performance Testing of Automobiles, and another by himself on European Research as to Wind-Resistance Losses of Automobiles. The latter will be based on observations made and data obtained during a European trip.

Problem One for Government

The automobile has created this traffic problem, but think how much more complex it would be if the same number of horse-drawn vehicles would block the streets, said Mr. Schwitzer in the paper he presented on Traffic and the Automotive Industry. He listed about a dozen ways in which the engineers have improved cars to increase safety and said that the time has come when we must look to the municipal and State governments to do their share. Among the needs, he mentioned proper legislation, a uniform system of enforcement, an adequate force of competent men to enforce the laws and regulations, definite right-of-way regulations, systematic education of highway users, widening and building streets to adapt them to present traffic, removal of street-cars and their replacement with motorcoaches or trackless-trolley vehicles, refusal to license motor-vehicles that cannot pass tests for safety, and restriction of parking in the streets.

In conclusion, Mr. Schwitzer expressed his conviction that "the day will come when each municipality of any size will employ a competent traffic engineer to solve its problems" and that "pressure should be brought upon the municipal authorities to eliminate the obsolete traffic-control equipment and replace it with some that will do the work."

Traffic Inadequately Controlled

Henry E. Todd, of the Automatic Signal Corp., next gave a paper that graphically presented the fact that traffic congestion, accidents and loss of life are increasing in this Country more rapidly than are motor-vehicles. His figures showed that deaths due to automobile accidents amounted in 1928 to 18 per 100,000 registered vehicles and in 1929 increased to 23 per 100,000, an increase of 25 per cent, while motor-vehicles increased only a few per cent. Switching to Indiana, Mr. Todd showed that the death rate per 100,000 vehicles in 1930 is 27.6 for the Nation and 34.4 in the State, showing that Indiana seems to be at least 30 per cent behind the Nation at large in safety measures and traffic control.

Later developments in the address and discussion brought out that traffic control is inadequate in the cities and State. In Indianapolis there are only 11 motorcycle traffic men who have time to patrol the streets, while scores of traffic officers are kept at corners to direct traffic by hand and semaphore. According to City Councilman A. H. Henry, they are using traffic lights and other equipment that are not only inade-

(*Continued on p. 724*)

Chronicle and Comment

Greetings! THROUGH the medium of THE JOURNAL, our officers extend holiday greetings to the members of a friendly Society. Although the technical activities of the S.A.E. may seem cold and without a great degree of warmth and sympathy, yet in reality friendship and a fellow-feeling are, after all, the most tangible and satisfactory assets of our work. In view of the fact that friendships established through the promotion of common interests are most worthwhile and enduring, it seems that the Society forms a very happy medium for the interchange of salutations at this period of the year.

Rockne Will Be There KNUTE K. ROCKNE, master mind of football, scholar, philosopher and renowned speaker, has agreed to address the Annual Dinner of the Society at Hotel Pennsylvania in New York City on the evening of Jan. 8. Mr. Rockne's discourse, according to Society members who have heard him, can be counted upon to contain a very lively combination of vigorous philosophy, human interest and sure-fire wit. In short, the Annual Dinner Committee has provided a speaker whose virile personality will assure a complete fulfillment of the desires of more than 1000 members who will attend the Dinner.

Charles F. Kettering, vice-president of the General Motors Corp., has secured a unique place of esteem in the hearts of all S.A.E. members. As Toastmaster at the Annual Dinner, "Ket" will do the honors as no one else could do them.

James Schermerhorn, of Detroit, who is known from coast to coast for his sparkling humor, will complete the very happy combination.

What's Ahead? NOW AND THEN we hear the remark that automobiles have reached the point where all are alike and that there is no real opportunity for improvement. Fortunately, that is but a minority report, for most of the outstanding representatives of the automotive fraternity are convinced that we are now entering a period of greater development than has been in evidence heretofore. At least there are great prospects for fundamentally sound advancement in motor-car engineering and production.

Two very refreshing articles along this line, quoted in part in this issue of THE JOURNAL, from the pen of Fredrick E. Moskovics, appeared in recent issues of *Automotive Industries* and should be read by engineers whose morale has become depressed along with stock-market quotations.

At a recent conference of engineers who have been active for years along constructive lines in the building of automobiles and essential units, a feeling of sincere optimism was expressed, fully confirming the observations made by Mr. Moskovics. One of these gentlemen called particular attention to the opportunities that exist at the present time, and do not exist during periods of peak production, for the study of improvements and their embodiment in the product. Another member described the advancements that are already under way and that will soon become evident in the way of more capable commercial vehicles that are better adapted to present-day requirements.

All things considered, we cannot help having extreme confidence in the future and in the very important part that will be taken by the automotive engineer who looks constructively beyond his slide rule and blueprints into the real demands that exist in the various branches of automotive transportation.

Growls from the Rear APPARENTLY the unseemly noises that originate in rear axles and at other places where gear meets gear are being attacked vigorously from various angles. At least the papers and discussion at the Cleveland Section meeting, as reported elsewhere in this issue, indicated that engineers have recognized a problem that demands technical cooperation aimed toward a solution.

With the higher powers and speeds now in vogue, it seems that rear axles are prone to complain. Scuffed gear surfaces and lapped bearings call for relief. Lead-soap greases are reported to offer a partial solution, but the gears and the bearings do not respond equally well to the same sort of treatment.

Motor-car engineers believe that great possibilities lie in the direction of improved lubricants. Lubrication engineers accept the challenge but suggest that motor-car engineers should recognize in their designs the type and availability of existing lubricants.

Great credit is due the Cleveland Section for bringing out for an airing a very important problem, the answer to which will be determined through the cooperation of the various agencies that are involved.

Traffic Engineers Organize ONE of the new professions brought into being by the motor-vehicle is that of street traffic engineering. Problems presented by increasing traffic congestion have been pressing for solution for some years, and a considerable number of engineers have turned their attention to study of the subject, particularly in the larger cities where the need is greatest.

Street and highway engineers from New York City, Chicago, Philadelphia, Boston, Baltimore, Pittsburgh and St. Louis met recently in New York City and founded a new National organization to be known as the Institute of Traffic Engineers. The officers elected are Ernest P. Goodrich, consulting engineer, of New York City, president; Dr. Miller McClintock, director of the Albert Russell Erskine Bureau of Street Traffic Research of Harvard University, vice-president; and Hawley S. Simpson, research engineer of the American Electric Railway Association, secretary-treasurer.

Committees have been appointed to prepare a course in traffic engineering for use in engineering schools, to clarify the terminology and nomenclature of the profession, and to study the whole problem of street traffic.

One of the primary objects of the new Institute is to stimulate research in street-traffic matters. Another is to encourage and foster traffic-engineering education in colleges of engineering. No great perspicacity is needed to foresee that opportunities will increase for the application of real engineering talent, supplemented with good training, to the problem of relieving traffic congestion and expediting the movement of persons and goods in the larger centers of population.

Aluminum Alloys
Used in Commercial Motor-Vehicles

Transportation Meeting Paper

By Frank D. Goll[1]

The paper is confined to a discussion of aluminum for commercial motor-truck bodies and tanks.

Following a statement that commercially pure aluminum is seldom used for structural parts except when alloyed with another element or elements such as copper, manganese, magnesium or silicon, and remarking upon new alloys available, the author considers the subjects of design, selection of a correct aluminum alloy for a particular purpose and like matters.

The advantages of aluminum bodies as to weight saving, low maintenance-cost, residual value and better appearance, are stated also, as well as the special advantages applicable to certain types of body now in operation. The paper also treats aluminum motor-truck tanks in some detail, and presents numerous statistical data in tabular form.

THE TREND in commercial transportation-equipment is toward the light, strong alloys of aluminum which, developed entirely during the last 10 years, are rapidly becoming the accepted structural materials in this line of engineering endeavor. The advantages of reduction in dead weight have long been apparent to transportation engineers, but it has been only since the advent of the strong aluminum-alloys in commercial shapes that these advantages have been fully demonstrated. The use of aluminum, excluding the powerplant, until say three years ago was confined largely to the low-stressed members such as side sheets, roof sheets and trimmings. At present, it is replacing other metals for the strength members in trucks, motorcoaches, steam and electric-railway cars, and all types of transportation equipment. In the transportation industry, the use of aluminum is well exemplified in the case of aluminum commercial motor-truck bodies and tanks. The paper is confined to a discussion of this recent development.

Commercially pure aluminum, that is, 99.0-per cent aluminum, with its high ductility and low strength, is used seldom, if ever, for any parts of transportation equipment; usually, it is alloyed with another element or elements, such as copper, manganese, magnesium or silicon. Many different alloys are marketed under various trade names. Of the Alcoa alloys, only seven are commonly used for commercial motor-truck bodies and tanks. The approximate chemical compositions of the wrought and cast aluminum-alloys are tabulated in Table 1.

The mechanical properties of 3S alloy depend upon the temper of the metal, which is determined by the amount of strain-hardening or cold-working given the metal during fabrication. Ordinarily, 3S alloy is produced in the following tempers: annealed, one-quarter hard, one-half hard, three-quarter hard and hard. These are designated 3SO, 3S¼H, 3S½H, 3S¾H and 3SH. This alloy can be annealed at a temperature of 800 deg. fahr.

Alloys 17S, 25S and 51S are known as the strong aluminum-alloys. Their maximum mechanical properties are produced by heat-treatment followed by the proper aging treatment. This may consist of either room-temperature aging or an artificial aging treatment. In 17S alloy, the aging takes place spontaneously at room temperature following the heat-treatment; hence, this alloy cannot be kept in the unaged condition. Alloys 25S and 51S, however, are aged artificially at higher temperatures and can be produced in the heat-treated condition without being aged.

In our company's designations, "W", attached to the end of the alloy number, represents the heat-treated condition; if the alloys are aged after heat-treatment, the symbol "T" is used. The strong alloys can be annealed after heat-treatment by holding them at a temperature of 800 deg. fahr. for at least 1 hr. after which they should be very slowly cooled to below 500 deg. fahr. In the annealed condition, the strong alloys are designated 17SO, 25SO and 51SO.

The casting alloys are designated by numbers only, as indicated in Table 1, and are referred to as No. 12 alloy, No. 43 alloy and No. 195-4 alloy. The No. 195-4 alloy differs from the other two in that it is heat-treated to improve its mechanical properties. The heat-treatment used is indicated in Table 2.

Design Considerations

The design of motor-truck bodies and tanks of aluminum is essentially the same as that of steel. Since the strong aluminum-alloys are comparable to the common

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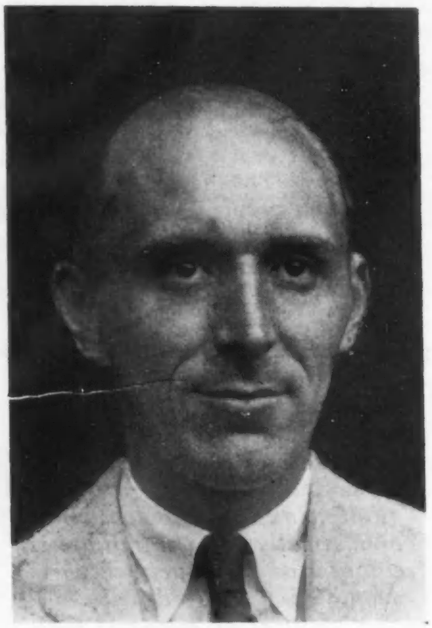
steels in strength, it is possible in replacing steel to use them, in most cases, section for section. This fact eliminates the necessity for any detailed discussion of design; there are, however, a few points of difference to consider.

The modulus of elasticity of aluminum alloys is 10,000,000 lb. per sq. in. as compared with 29,000,000 lb. per sq. in. for steel. This means that, under a given stress, aluminum will deflect about 2.9 times as far as steel. For most parts of bodies, this fact need not be considered, since the spans are short and deflection is not objectionable. But because it contributes to more resilience in a structure, greater deflection is often desired. In a few places, such as for flooring, rigidity must be considered. When aluminum-alloy sheet is employed in place of steel for an unsupported span of metal flooring, either the thickness of the aluminum sheet should be increased or the span reduced. If the same span is retained, the thickness of the sheet should be increased about 40 per cent over that of the steel; if the same thickness of sheet is maintained, the span should be reduced approximately 30 per cent.

If 3S alloy is used in place of steel, it is often desirable to increase the section by about 40 per cent, thereby gaining equivalent rigidity. This increase in section doubles the section modulus and reduces the stress in the extreme fiber to one-half as much as in the extreme fiber in the thinner steel member. Since 3S alloy possesses about one-half the strength of steel, it follows that the aluminum structure is just as strong as the steel structure, but at a saving of 50 per cent in weight. This basis of reasoning is used particularly in the design of aluminum motor-truck tanks.

Impact stresses in the body, resulting from imperfections or obstructions on the highway, are probably the most devastating encountered in normal operation. Since tests on built-up structures of aluminum and steel have shown that the impact effects are no worse on the former than on the latter, it is recommended that steel practice be followed in designing aluminum bodies and tanks for impact.



FRANK D. GOLL

TABLE 1—APPROXIMATE COMPOSITION OF ALUMINUM ALLOYS

	Approximate Composition, Per Cent				
	Alloy[a]	Copper	Manganese	Magnesium	Silicon
Wrought	3S	...	1.25	...	...
	17S	4.0	0.50	0.5	...
	25S	4.5	0.80	...	0.8
	51S	....	....	0.6	1.0
Cast	12	8.0	....	...	...
	43	...	....	...	5.0
	195-4	4.0	....	...	...

[a] The alloy numbers referred to are those of the Aluminum Co. of America.

Aluminum-Alloy Selection

In selecting the correct aluminum-alloys for the various parts of a motor-vehicle body, the three important points to consider are strength, workability and price. Since aluminum bodies are higher priced, the cheapest alloy which has sufficient strength and workability to meet satisfactorily the requirements always should be used. Because of a lack of knowledge of aluminum, the body builders to whom this metal is new often will insist upon the strongest alloys for all parts, irrespective of need; this naturally results in a body which is decidedly over-priced and under-stressed. While it is impossible to state definitely that certain alloys should be used at all times for the same part of a body, it is felt that the following text describes the good practices in common use today.

Alloy 3S is well adapted for parts where strength is not of primary importance and where welding is necessary. This alloy has been used for years for panels and is well known to most body builders. It has the advantage of being the cheapest alloy and should be used wherever its strength permits. The roof and panel sheets on van-type bodies are usually of 3S alloy in the hardest temper suitable to the necessary forming. It is also used exclusively for truck tanks, principally because of its excellent welding and forming characteristics.

Sheet, in 3S alloy, is produced in two finishes; flat sheet, which has a bright finish, and gray plate which, as its name implies, is dull. If the panels are to be left unpainted and are to be polished or burnished, flat sheet should be used; but if the panels are to be painted, gray plate should be employed because its matté surface will receive and hold the paint better. Then too, gray plate is cheaper than flat sheet. In addition to panels, 3S alloy is used for low-stressed

TABLE 2—DATA ON HEAT-TREATMENT OF ALUMINUM ALLOYS

	Alloy	Heat-Treating Temperature, Deg. Fahr.	Approximate Time of Heating[b] Min.	Quenching[c] Medium	Aging Temperature, Deg. Fahr.	Time of Aging
Wrought	17S	940-960	15-60	Cold Water	Room	4 days[d]
	25S	960-980	15-60	Cold Water	285-295	8-15 hr.
	51S	960-980	15-60	Cold Water	310-320	18 hr.
Cast	195-4	960	12 hr.	Hot Water	....	....

[b] Depends on size and amount of material.

[c] It is essential that the quench be made with the minimum time-loss in transfer from the furnace.

[d] More than 90 per cent of the maximum properties are obtained during the first day of aging. The mechanical properties of these alloys are given in Table 3.

TABLE 3—TYPICAL MECHANICAL PROPERTIES OF ALUMINUM ALLOYS

	Alloy and Temper	Weight, Lb. per Cu. Ft.	Tension: Yield-Point, Lb. per Sq. In.	Tension: Ultimate Strength, Lb. per Sq. In.	Tension: Elongation in 2 In., Per Cent	Compression: Yield-Point, Lb. per Sq. In.	Compression: Ultimate Strength, Lb. per Sq. In.	Shear Strength, Lb. per Sq. In.	Endurance Limit, Lb. per Sq. In.	Brinell Hardness Number
Wrought	3SO	171	5,000	16,000	40	5,000	16,000	11,000	6,000	28
Wrought	3S½H	171	18,000	21,000	20	18,000	21,000	14,000	9,500	45
Wrought	3SH	171	25,000	29,000	10	25,000	29,000	16,000	10,500	55
Wrought	17ST	174	35,000	58,000	20	35,000	58,000	35,000	15,000	100
Wrought	25SW	174	25,000	48,000	18	25,000	48,900	30,000	14,500	80
Wrought	25ST	174	35,000	58,000	20	35,000	58,000	35,000	15,000	100
Wrought	51SW	168	20,000	35,000	24	20,000	35,000	24,000	10,500	64
Wrought	51ST	168	35,000	48,000	14	35,000	48,000	30,000	10,500	95
Cast	12	178	14,000	22,000	2	16,000	38,000	20,000	8,500	65
Cast	43	166	9,000	19,000	4	9,600	25,000	15,000	6,500	40
Cast	195-4	174	16,000[e]	31,000	8	27,000	43,000	27,000	6,000	65

[e] Natural aging will increase gradually the yield-point to 20,000 lb. per sq. in. or more. This requires from 3 to 6 months. The safe design-stresses of these alloys are given in Table 4.

rivets, such as those used for fastening the panels. Practically all of the piping on motor-truck tanks is of 3SH I.P.S. tubing.

Alloys 17ST, 25ST and 51S

These alloys, with mechanical properties similar to those of ordinary steel, are used for the important strength-members. The dividing line in the choice of alloy is often indefinite because, in some commodities, the price is the same. It should be borne in mind that 17ST alloy probably will withstand more severe forming than will 25ST alloy, and this is sometimes the deciding factor. If corrosion resistance is of prime importance, 17ST alloy is somewhat better than 25ST alloy.

Sheet is produced in both 17ST and 25ST alloys in the same gages, widths and lengths. Considering the difference already mentioned, 25ST alloy should be used where possible since it is slightly cheaper than 17ST alloy. Structural shapes are produced and carried in stock in both alloys. The more common Carnegie shapes of angles, channels and Z-bars are available in lengths up to 85 ft. Wire, rod and bar, are made in both alloys at the same price; so, the selection is based entirely on the required characteristics. Rivets, bolts, nuts, screws and, in fact, all screw-machine products are standard in 17ST alloy.

Alloy 51S in the unaged or "W" condition is very workable and is adapted to severe forming-operations. Usually, after forming, it is aged to 51ST alloy, in which condition it has the same yield-point as have 17ST and 25ST alloys. In the "W" condition, it also welds easily and is sometimes used where 3S alloy is not strong enough. Sheet in 51S has the same price as 25S alloy. The endurance limit of 51ST alloy, as shown by Table 3, is only 10,500 lb. per sq. in. as compared with 15,000 lb. per sq. in. for 17ST and 25ST alloys. If the stresses in the structure permit, it can be used in place of 17ST and 25ST-alloy shapes with an appreciable saving in cost.

Drop-forgings can be produced in any of the wrought alloys but, since strength is generally required, the strong alloys are more commonly used. Alloys 25S and 51S are well adapted to the forging processes and, hence, are standard. After forging, these alloys are usually heat-treated and aged.

No. 12 alloy, S.A.E. No. 30, is the most common casting-alloy used and generally replaces cast iron section

TABLE 4—DESIGN STRESSES FOR ALUMINUM ALLOYS

	Alloy and Temper	Tension, Lb. per Sq. In.	Compression,[g] Lb. per Sq. In.	Bearing, Lb. per Sq. In.	Shear, Lb. per Sq. In.	Endurance, Lb. per Sq. In.
Wrought	3SO	4,000	4,000	4,000	3,000	4,800
Wrought	3S½H	6,000	6,000	7,000	3,500	7,600
Wrought	3SH	8,000	8,000	10,000	4,000	8,400
Wrought	17ST	15,000	15,000	19,000	9,000	12,000
Wrought	25SW	12,000	12,000	16,000	7,500	11,600
Wrought	25ST	15,000	15,000	19,000	9,000	12,000
Wrought	51SW	9,000	9,000	11,000	6,000	8,400
Wrought	51ST	14,000	14,000	16,000	7,500	8,400
Cast	12	5,000	9,000	9,000	5,000	6,800
Cast	43	5,000	6,000	6,000	4,000	5,200
Cast	195-4	7,000[f]	11,000	14,000	7,000	4,800

[f] Value given is for an unaged casting. Where the casting is to be aged for 3 to 6 months before use, a design stress of 9,000 lb. per sq. in. is safe provided fatigue is not an important item.

[g] For short stiff members.

for section. No. 195-4 alloy, with its higher strength, is more nearly comparable with malleable iron. By increasing the sections slightly and changing the heat-treatment, it can often be used to replace steel castings. No. 43 alloy finds its use primarily where leak-proof castings are required or where the castings are to be welded to the structure; such as in manhole domes, outlets and the like. Tank pipe-fittings are standard I.P.S. fittings made in this alloy. Table 4 shows design stresses.

Forming Aluminum Alloys

In selecting the alloy for a part which must be cold-formed, the first point to consider is the physical properties required in the finished piece. If the properties of 3S alloy are sufficient, then this alloy in the hardest suitable temper should be used. If the piece requires greater strength than is possible with 3S alloy, then 51SW alloy may be employed. After forming, if greater strength is desired than can be obtained in 51SW alloy, it can be aged to 51ST alloy, but 51ST alloy does not cold-form well. Of the heat-treated strong-alloys, 17ST alloy forms best, with 25ST alloy only slightly less formable. Table 5 gives the approximate bend radii for 90-deg. cold-bends.

TABLE 5—BEND RADII FOR ALUMINUM ALLOYS; 90-DEG. COLD BENDS[a]

Alloy and Temper	Bend Radii for Different Thicknesses of Sheet		
	1/16 in. Sheet	1/8 in. Sheet	1/4 in. Sheet
3SO	0	0	0
3S½H	0	t	t
3SH	t	$3t$	$4t$
17SO	0	0	t
17ST	$2t$	$3t$	$5t$
25SW	$2t$	$3t$	$5t$
25ST	$2t$	$4t$	$6t$
51SW	t	$2t$	$4t$
51ST	$3t$	$6t$	11

[a] The values given represent average shop-practice for production conditions. Considerably shorter radii can be used if special care is taken. To use short radii successfully, sharp corners and burrs should be removed from the edges of the sheet near the bend line. This minimizes the tendency for cracking to start from the edges. Smooth, clean, well-lubricated tools should be used. It is preferable that the axis of the bend be at right angles to the direction of rolling. In the table, t represents the thickness of the sheet.

If the shape to be formed is too severe for cold-forming then, like steel, it can be hot-formed. Heating the alloys to around 400 deg. fahr. improves their ductility and is often sufficient. This temperature is not high enough to anneal the material and, therefore, does not cause any appreciable drop in physical properties; however, over-aging will result if the material is held at this temperature for much longer than 15 min.

For the most difficult forming operations and where the part may later be heat-treated, the metal can be heated to 650 to 850 deg. fahr. and formed according to steel practice. Very often the forming comes at a part of the member which is lower stressed; in such cases, the portion to be formed should be heated only locally and left in the non-heat-treated condition. This practice is not recommended unless it is definitely decided that the annealed portion is sufficiently strong.

If the shape to be hot-formed is such that it does not permit heat-treating after forming, it can be formed and heat-treated simultaneously. This can be accomplished by preheating the metal to the heat-treating temperature of 890 to 940 deg. fahr. and transferring it to the forming tools with the minimum loss of time, thereby effecting a die quench with the relatively cold tools. Hot-forming of this nature is generally performed on 17ST alloy because, after forming, it develops the mechanical properties of the fully heat-treated metal without subsequent artificial aging.

Riveting and Welding Methods

Both aluminum and steel rivets are used for assembling aluminum bodies. Rivets of 3S alloy, driven cold, are generally used for riveting panels, roofs and other low-stressed parts. If the joint must develop maximum strength, either 17ST-alloy or steel rivets should be used. In using 17ST-alloy rivets, it is customary to heat-treat the rivets first and then drive them cold. For the larger sizes, the rivets should be heated to the heat-treating temperature, 940 to 950 deg. fahr., and driven while hot. Rivets of 17ST alloy are usually cold driven in sizes up to and including 3/8 in., and hot driven in the larger sizes. While the use of steel rivets is satisfactory for concealed parts, it is certainly not desirable for a point where there is the possibility of the steel streaking the aluminum member and spoiling the appearance of an otherwise good-looking job.

The aluminum alloys can be easily and successfully welded and, while it is true that it requires a different technique than for steel and other metals, it is not difficult to train men for such work. Fusion welding by oxy-hydrogen and oxy-acetylene is the method most commonly used at present, but rapid strides are being made in the art of electric-arc welding. While the strong alloys in the fully heat-treated and aged condition can be welded, the heat of welding spoils the heat-treating effects so that poor joint-efficiency is the result. Welding of the fully heat-treated alloys is analogous to welding spring-steel. Welds are used most often in 3S-alloy material although, in a few instances, parts of bodies have been welded in 51SW alloy.

Corrosion Effects

The subject of corrosion of aluminum alloys in transportation equipment is one which is over-emphasized and very often is exaggerated. The rusting of ferrous metals is acknowledged by everyone, the result being that they are always carefully protected from the elements. If aluminum alloys were always given this same protection, their corrosion would be negligible.

The joints in which moisture may be trapped are the points of least resistance and, to eliminate this danger, it is necessary only to paint the joint before assembly. A bituminous paint is probably the best for this purpose. If the body is to be left in the natural color, the black paint in the joints is objectionable and an aluminum paint made with a varnish base, or something of that nature, can be used instead. Paint coatings can be applied to aluminum bodies, employing the same materials and procedure as for any other metals. If the aluminum body is to be left in the natural metal-finish it should, after polishing or burnishing, be given several coats of clear lacquer or varnish.

It is not to be understood that an unpainted or unprotected aluminum body will always show evidences of corrosion; many such bodies are in use which, after years of service, are giving no trouble. An unprotected body might, though, under severe climatic conditions show some corrosion; therefore, it is recommended that

the proper precautions be taken when the assembly is made.

Weight Saving and Its Cost

The analyses of hundreds of well-designed bodies have brought forth valuable criteria for checking the weight saving and additional cost of aluminum bodies over bodies constructed of steel. Provided the steel body was well designed and a complete substitution was made, the aluminum body should weigh only 35 to 50 per cent as much, and the additional material cost should be around 20 cents per lb. of weight saved. The reason for this is simple; in an aluminum body weighing 40 per cent as much as a similar steel body, 2 lb. of aluminum are used for every 5 lb. of steel replaced. At an average of 38 cents per lb., the aluminum material would cost 76 cents and would replace 5 lb. of steel at 3 cents per lb., or 15 cents. This would account for an additional cost of 61 cents. But 3 lb. of weight have been saved at an additional cost, therefore, of 20 1/3 cents per lb. If 1000 lb. of weight is saved in a body, properly designed, the material will cost around $200 additional.

While for the conventional types of aluminum commercial-bodies the cost of fabrication is generally the same as or less than for steel, it does not follow that the purchaser can expect to buy them at an additional cost of 20 cents per lb. of weight saved. The body builder carrying a larger inventory investment and marketing a higher-priced article is entitled to a larger profit. Further, aluminum bodies, being of higher grade, are rightfully receiving better workmanship and closer supervision.

It is difficult to make a definite cost and weight comparison between aluminum and wood bodies. The cost of a wood body depends largely upon the class of workmanship employed, the material cost being only a small percentage of the selling price; however, aluminum bodies, with their lower assembly but higher material cost, compete with good all-wood bodies in weight and selling price.

The various fabricated commodities are continually becoming less expensive because of the improved methods of manufacture. For example, the recent introduction of strong-alloy rolled structural-shapes saves the purchaser an appreciable amount over shapes of the same strength produced by the extrusion process. The development of new and stronger alloys will result in lighter and less-expensive bodies. In this connection, there is a new wrought-alloy still in the experimental stage which seems to be very promising. It has the forming and welding characteristics of 3S alloy, but is approximately 50 per cent stronger; in the hard tempers, its yield-point is the same as that for strong alloys.

Advantages of Aluminum Bodies

While aluminum panels and body sheets have been used for years, it was not until 1928 that the first all-aluminum motor-truck body was built. In the short space of two years, the demand for light-weight equipment has become so great that, today, one finds hundreds of aluminum bodies in operation and many more under construction. Body builders who, two years ago, had never heard of aluminum bodies, are now producing more of them than they are building of steel. The first aluminum-bodies were sold entirely on the basis of increased payload; that is, to carry more load and still stay within the highway load-limit. This was and still is the most compelling argument. The operators have discovered though that aluminum bodies have other advantages which, in themselves, justify the higher cost. The result is that there are many such bodies now in service. The four principal advantages of aluminum bodies are weight saving, low maintenance-cost, residual value, and better appearance.

Reduction in dead weight is most profitably taken advantage of by increasing the payload within the same gross load-limit. In case increased payload is not desired, the weight saved often permits the use of a lighter and, therefore, cheaper chassis; or, with the same chassis, schedules will be improved because of the higher speeds which are possible and the less-frequent gearshifting that is required. Either method results in lower operating-cost.

The fact that aluminum does not rust eliminates the necessity for frequent painting; the painting that a steel body requires throughout the course of its life is often sufficient to more than offset the additional first cost of the aluminum body.

Should the aluminum body become wrecked or obsolete, the material has a scrap value of around 65 to 70 per cent of the going ingot-value; whereas, steel is practically worthless. This is an important fact and always should be kept in mind when considering new equipment.

TABLE 6—STEEL AND ALUMINUM-BODY COMPARISON

Maximum total weight permitted by Pennsylvania "W" License, lb.		22,000
Weight of chassis, Mack AB 2½-ton, lb.	7,260	
Weight of steel body, mechanical hoist and high-lift mechanism, lb.	4,600	
Total weight with steel body, lb.		11,860
Weight of aluminum body, mechanical hoist and high-lift mechanism, lb.	2,800	
Total weight with aluminum body, lb.		10,060
Payload with aluminum body, lb.	11,940	
Payload with steel body, lb.	10,140	
Gain per load, lb.		1,800
Average number of trips per day		10
Gained per day per truck, lb.		18,000
Number of days to gain free one day's work of steel job equals (101,400/18,000), or		5.63 days
Days' work gained per year of 300 days		53.3
Operating cost per truck per day		$25.00
Cost of 53.3 days' work saved per truck per year		$1,332.50
Added investment for aluminum body and hoist		$645.00
Gain in capacity for $645 worth of additional investment, per cent		17.7
Return on additional investment, per cent		206.0

If the paint on an aluminum body is scraped off, there will be no rust streaks to spoil its appearance. Then too, the natural-finished aluminum-bodies have an advertising value in that they attract favorable attention.

Aluminum Bodies Now in Operation

As to the special advantages applicable to certain types of body, the examples chosen for illustration represent, in general, the aluminum-body industry at present. The data given were obtained from the various companies mentioned, and are quoted with their permission.

In the fall of 1928, the Auto Truck Equipment Co., of Pittsburgh, delivered its first high-lift dump-body to the Pittsburgh Coal Co. Because of the saving in

FIG. 1—ALUMINUM HIGH-LIFT DUMP-BODY OF 6½-CU. YD. CAPACITY WHICH REPLACED A FUEL BODY OF ONLY 5-CU. YD. CAPACITY

weight, the aluminum body shown in Fig. 1 had a 6½-cu. yd. capacity, while the steel body it replaced had only a 5-cu. yd. capacity. The cost figures shown in Table 6 indicate the advantages derived.

TABLE 7—DATA ON AN ALUMINUM ICE AND COAL BODY

	Lb.
Weight of truck with steel body	4,500
Weight of truck with aluminum body	3,800
Weight saving	700
Maximum payload with aluminum body	5,500
Maximum payload with steel body	4,800
Gain in capacity per load	700
Number of trips necessary to deliver ice on an average route per day with steel body, the three loads consisting of two 4800-lb. loads and one smaller load	3
Number of trips necessary to deliver ice on an average route per day with aluminum body consisting of two 5500-lb. loads	2
Time saved per truck per day	1 hr.
Approximate number of days required to gain one free day's work (based on a 7-hr. average working-day)	7 days
Day's work gained per summer, 150 hr., or	21.4 days

Since the original body, 18 additional bodies of various sizes have been purchased by the same company and, according to present indications, it will standardize on all-aluminum bodies when its present steel bodies are replaced. A recent inspection of the first all-aluminum unit of this company showed that it had withstood two years of service with but little wear; perhaps better than a steel body for the same length of time.

The successful operation of the foregoing company's bodies has caused other companies in the same line to follow its example. The Heil Co., of Milwaukee, has delivered twenty-seven 2½-ton open bodies to the Wisconsin Ice & Coal Co., Milwaukee, for the distribution of ice and coal, as shown in Fig. 2. These bodies are mounted on Ford, Model AA, chassis and are 8 ft. 2 in. long, 5 ft. 2 in. wide and 28 in. high. Since these trucks made coal deliveries principally to homes, and even tons are always ordered, the weight saving could not be fully taken advantage of in hauling coal, and the increased payload of the aluminum body could be realized only during the part of the year ice is carried. For this reason, the tail gate, which is used only in hauling coal, was fabricated from steel. The economy figures are, therefore, based on a saving during the ice season only, but the advantages of a light body are realized during the winter in permitting faster delivery-schedules, less wear and tear on the chassis, and less consumption of gasoline. The figures are shown in Table 7.

TABLE 8—ADDITIONAL PAYLOAD DUE TO ALUMINUM BODY

In one week of 5½ days the truck makes 25 trips, the extra payload per trip being due to the weight of the alumium body, lb.	2,025
Average earnings per ton	$0.87
Weekly saving (2,025/2,000 × 0.87 × 20), or	$22.02
Annual savings, 50-week year	$1,101.00
Extra cost of aluminum body	$533.58

Gerhard Kopmeier, of the Wisconsin Ice & Coal Co., states that paint adheres to the aluminum bodies much better than it does to the steel bodies. This is due simply to the fact that the aluminum bodies do not rust.

The Milwaukee Western Fuel Co., Milwaukee, is also operating three aluminum coal-carrying bodies; two are high-lift hopper-types and the third a high-lift dump-truck. These bodies were left in the natural aluminum finish and are protected by a coat of clear lacquer. The weight saving and economies are comparable with those of the two foregoing companies.

The Manegold Stone Co., Milwaukee, is operating two aluminum dump-bodies for hauling crushed rock. The aluminum body is 11 ft. 6 in. long, 6 ft. 6 in. wide and 39 in. high. The height has been increased 4 in. over that of the steel body to accommodate the increased load. Sheet of 25ST alloy and structural shapes of 51ST alloy were used to replace high-carbon steel. The weight of the steel body was 3200 lb., that of the aluminum body was 1550 lb., and the weight saved was 1650 lb. The largest payload permissible for the steel body under the Wisconsin highway load-limit is 20,620 lb. Taking the weight saving as increased payload, the payload for the aluminum body is 22,270 lb., an approximate increase of 8 per cent. Since the operating cost per truck per day is $30, a saving of $2.40 per day will be effected and, within approximately 15 months, the additional cost of $1,000 will be written off.

FIG. 2—ALUMINUM 2½-TON OPEN BODY FOR THE DISTRIBUTION OF ICE AND COAL

The 16-cu. yd. coal-carrying body of the Seaconnet Coal Co., Providence, R. I., built by the Providence Body Co., represents the largest body of this type ever built. The over-all length is 13 ft. 10 in., the width 8 ft. 6 in., and the height 4 ft. 4 in. The structural members are of 51ST and 17ST-alloy extruded shapes, while the body sheets are of 25ST alloy. Hot-driven steel-rivets were used throughout, and all joints were thoroughly coated with bitumastic paint. The aluminum construction permitted a 2025-lb. additional payload without exceeding the 40,000-lb. gross-load allowable in Rhode Island. The figures are given in Table 8.

Additional cost is written off in 24 weeks, or the original additional investment of $533.58 shows a return of 206½ per cent yearly. In addition to the figures in Table 8, it should be remembered that the scrap value of this body is about $240. This company states that the foregoing figures are worked out on a very conservative basis in that the truck will probably make nearer 40 than 25 trips per week.

Armour & Co., of Pittsburgh, has had a meat delivery truck with an aluminum body in service for nearly two years. The body is 146 x 66 x 15 in. It weighs 610 lb. as compared with 1400 lb. for a steel body of similar design. The additional cost is around $200. The Peters Packing Co., McKeesport, Pa., is also operating

FIG. 3—TYPE OF ALUMINUM BODY USED FOR THE DELIVERY OF WHOLESALE GROCERIES

a similar body. The weight saving here has resulted in an increased payload of 1520 lb. The Fried & Reineman Packing Co., Pittsburgh, also increased the capacity of its meat-delivery trucks approximately 1000 lb. by the use of aluminum.

In the hauling of garbage, the corrosion-resisting qualities of aluminum are especially advantageous. The Allegheny Garbage Co., Pittsburgh, is operating trucks with all-aluminum bodies which show a weight saving of 900 lb. each. These bodies, in addition, promise to outlast many steel bodies.

An interesting example of special equipment is found in the trucks of the Schumaker Wall Board Corp., Los Angeles. These trucks with aluminum bodies are used for hauling dry gypsum plaster. A maximum payload of this company's steel unit is 17.4 tons. With no increase in gross weight, the aluminum unit hauls 20.7 tons, an increase of 3.3 tons. Inasmuch as this unit makes six round trips per day, one trip or approximately 20 tons of payload is gained each day.

The Keystone Stores Co., Pittsburgh, operates nine all-aluminum bodies, of the type shown in Fig. 3, for the delivery of wholesale groceries. Staying within the Pennsylvania State weight-limit, the aluminum bodies have a payload of 15,800 lb., while the steel bodies have a payload of only 14,000 lb. The aluminum body, therefore, shows an increase of 1400 lb. in payload. These trucks each make one trip per day and in approximately 10 days gain one free load, or in one year approximately 30 days. With an operating cost of $25 per day, the gross savings per year will be about $750 and, after the $400 increased cost of the aluminum body, has been written off, the $750 is clear profit.

Unusual Special Types

Early in 1928, the Motor Haulage Shop & Garage Corp., Brooklyn, N. Y., placed in service two insulated aluminum trailer-bodies to transport frozen hogs from the Swift slaughter house in Harrison, N. J., to its packing house in Jersey City, a distance of 7 miles. Until that time, the product had been hauled in railroad refrigerator-cars which had to be iced and required 24 hr. for the round trip. The aluminum trailer-bodies could make the trip in about 45 min. and this time is short enough to permit the frozen hogs to pass from one point to the other without substantial rise in temperature.

The design of these bodies is rather unusual because of the fact that the entire load, a maximum of 20,000 lb., must be suspended from the roof. This accounts for the unusually rugged construction necessary to withstand the racking stresses set up by this load in passing over a rough road. The structural shapes are of 17ST and 51ST-alloy extruded sections and the side sheets are of ⅛-in. 51ST alloy. The insulation is Balsa Met-L-Wood, consisting of 1⅛ in. of balsa wood faced with 12-gage 3SH-alloy sheet. The entire structure was assembled with 17ST-alloy rivets heat-treated just before driving. Each trailer makes 10 loaded trips per day and carries 2.84 tons more payload than would be possible if the body were made of steel. Since the trailers operate over a distance of 7 miles, the daily increase in payload is about 200 ton-miles, or 60,000 ton-miles per year. On the basis of a cost of 3 cents per ton-mile, which is probably a very conservative figure, each of these bodies would yield $1,800 per year more net profit than would a corresponding job made of steel.

A completely aluminized van-type motor-truck body has been constructed by Rauch & Lang, Inc., Chicopee Falls, Mass., for the Fisk Rubber Co. Two of these bodies have been built. They are 18 ft. 6 in. x 6 ft. 6 in. x 7 ft. 4 in. The structural members are of 17ST alloy and the sheet is of 3S alloy. The weight of the aluminum body is 2650 lb., while the weight of a similar steel and wood body is 6000 lb. The use of aluminum has, therefore, resulted in an increase in payload of over 1½ tons.

The Red Line Transfer Co., Los Angeles, operates three 15 x 7 x 7 ft. all-aluminum vans which replaced composite steel, wood and plymetal construction with a saving of 2300 lb. One is shown in Fig. 4. These vans are in the natural finish and present a very striking appearance.

Braun Bros. & Co., Pittsburgh, have a bakery delivery-truck with a body composed entirely of aluminum alloys. This replaces a steel and wood body with a saving of 1600 lb., and makes possible the use of a smaller chassis. The Colonial Baking Co., St. Louis,

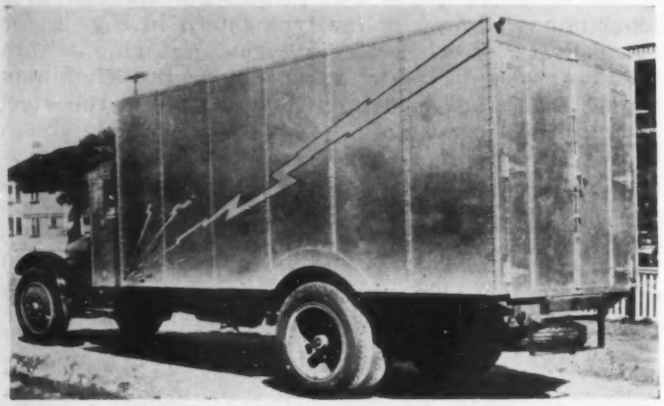


FIG. 4—ALL-ALUMINUM VAN WHICH REPLACED COMPOSITE STEEL AND WOOD CONSTRUCTION AT A SAVING OF 2300 LB.

owns 15 similar bodies of a smaller size in which the weight-saving is 500 lb.

The weight of an ice-cream delivery-body, because of necessary insulation, is very high relatively to that of the payload. The Meyer Body Co., Buffalo, N. Y., pioneers in light ice-cream carrying-bodies, is building bodies of aluminum in which a saving in weight of 1522 lb. is effected. This type is shown in Fig. 5. The reduction in weight makes possible an increase in payload of 200 gal. of ice cream. One of these bodies has been placed in service by the Liberty Dairy Products Corp., of Pittsburgh.

The Wangler Co., Pittsburgh, has built six bodies for the Rieck McJunkin Dairy Co., Pittsburgh, for the hauling of milk in cases. The weight saving is 900 lb. per body.

The Railway Express Agency, New York City, has recently purchased 86 aluminum bodies of 2½ and 3½-ton size. A saving of 660 lb. was effected on the 2½-ton body and a saving of 740 lb. on the 3½-ton body. While light weight is desired, the saving in weight cannot be utilized by increased payloads because of the character of the material usually handled; in better than half the cases, volume is the limiting feature rather than weight. Light gross-weight, however, is an important factor in the service which they render, and by taking weight out of the body, increased speeds are permissible particularly in hilly or mountainous country.

While the lighter load will effect a definite saving in operating cost, the real justification for the use of aluminum lies in the important feature of saving in maintenance cost by the greater corrosion-resisting characteristics of aluminum materials. The fact that the Railway Express Agency, with its knowledge of transportation costs, has written aluminum into its specifications for its standard bodies mounted on all the various types of chassis, should be definite proof that aluminum for this type of application is economical.

Aluminum Tanks

The first aluminum motor-truck tank in the United States was completed a year ago. It was built by the Standard Steel Works, Kansas City, Mo., and first exhibited at the 1929 International Petroleum Exposition in Tulsa, Okla. One of these units is shown in Fig. 6. The weight saving and resulting increase in capacity were so astounding that immediate inquiries were received by the various tank manufacturers. This resulted in many of the leaders entering the field. While the general and weight-saving advantages of aluminum motor-truck tanks are the same as for truck bodies, there are several additional advantages applicable to tanks alone. They are as follows:

(1) Aluminum tanks enable the delivery of gasoline of higher purity. Aluminum does not scale as does iron, and therefore there is no contamination of the gasoline.

(2) If left in the natural finish, the high reflectivity of aluminum results in a much lower inside temperature, thereby reducing evaporation losses. This is particularly valuable in long hauls in warm climates.

(3) Greater safety is afforded in that aluminum will not strike a spark from impact with any metal or material.

Weight-Saving and Economy Figures

The following paragraphs give the weight savings and, in some cases, the economy figures on a few of the aluminum motor-truck and trailer tanks that are in use at present.

The 2400-gal. aluminum tank built for the Tulsa exhibition weighed 2775 lb. empty, and replaced a 2000-gal. steel tank weighing 5545 lb. The gross weight of the aluminum tank with load was 22,715 lb., as against 22,845 lb. for the steel tank. There is, therefore, an increase in capacity of 20 per cent, with a decrease in dead load of 130 lb. The additional selling price of the aluminum tank was approximately $1,500. Truck-tank operators state that ½ cent per gal. is a very conservative figure for city delivery, and that a trailer tank such as this should average five trips daily. The increased tank-capacity of 400 gal., therefore, would produce an increase of 2000 gal. delivered daily which, at the delivery cost of ½ cent per gal., will net a saving of $10 per day. The added investment of $1,500 would, therefore, be written off in 150 days, and the increased capacity would result in a return of 200 per cent for a 300-day year.

In March, 1930, the Davis Welding & Mfg. Co., Cincinnati, Ohio, delivered to the National Refining Co., Cleveland, a 750-gal.-capacity aluminum-tank, mounted on a Fruehauf drop-frame aluminum semi-trailer, as shown in Fig. 7. The weight-saving data on this unit is given in Table 9. If the saving in dead weight of 1920 lb. had been utilized in increased capacity, the aluminum tank would have held an additional 300 gal.; that is, 1050 instead of 750 gal.

FIG. 5—LIGHT TYPE OF ICE-CREAM-CARRYING BODY IN WHICH A SAVING IN WEIGHT OF 1522 LB. IS EFFECTED

Fig. 6—The First Aluminum Motor-Truck Tank of the Type Shown Was Completed in the Fall of 1929

S. A. White, of the National Refining Co., states that the reduction in weight permits the use of a smaller tractor, thereby resulting in a net increased cost of the complete unit of only $850. Mr. White also states that, because of the lower operating-cost of the smaller chassis, the increased tire-mileage and less frequent repainting, the total yearly saving will be at least $235 which, on the increased investment of $850, means an annual return of 27.6 per cent, and the increased cost can be written off in 3½ years.

This type of equipment is usually wholly depreciated in 10 years; in that case, the scrap value of 2200 lb. of aluminum at about 16 cents per lb., or $352, must be credited against the increased cost. The additional cost at the end of 10 years is, therefore, the difference be-

Fig. 7—A 750-Gal.-Capacity Aluminum-Tank Mounted on a Drop-Frame Aluminum Semi-Trailer

tween $850 and $352, or $498; but, for the 10 years, the saving has been at the rate of $235 per year or $2,350, which, after deducting the additional cost at the end of 10 years, $498, gives a total profit of $1,852 on the additional investment.

The Heil Co., Milwaukee, has produced a tank similar to that of the National Refining Co.'s tank except that part of the weight saving has been put into increase in capacity. The aluminum tank, built for the Pure Oil Co., Chicago, for example, as shown in Fig. 8, is of 900-gal. capacity and replaces a 750-gal. steel tank; but when both tanks are filled with gasoline, the aluminum tank still weighs 470 lb. less.

General Advantages

Aluminum tanks permit the hauling of greater loads than was ever possible with steel construction. The Three-D Distributors, Fort Worth, Tex., are operating a train consisting of one 3325-gal. aluminum semi-trailer tank and one 2875-gal. aluminum six-wheel trailer-tank. This 6200-gal. load represents an increase in capacity of 24 per cent over that of the same unit constructed in steel. The 5000-gal. steel unit, loaded, would be up to the highway load-limit. A similar unit is in operation by the Sun Oil Co., Philadelphia. This company's train consists of a 3500-gal. straight-frame truck-tank mounted on a six-wheel chassis, and a 3000-gal. straight-frame trailer-tank, mounted on a four-wheel trailer. These tanks weigh, complete, approximately 0.8 lb. per gal.; for similar steel tanks, this figure would be around 2 lb. per gal.

While all the aluminum truck-tanks in operation to date are for the transporting of gasoline, tanks are being constructed for hauling milk; and, inasmuch as chemicals, fruit juices, malt, syrup, glucose, corn oil and similar commodities are commonly hauled by truck tanks, it is natural to assume that in time aluminum tanks will be used for these products. They are now commonly carried in glass-lined steel-tanks and, by replacing such a tank with an aluminum tank, the capacity can probably be increased 30 to 50 per cent. Further, the glass-lined tank does not lend itself to drop-frame construction as does the aluminum tank. The lower center of gravity resulting from drop-frame construction permits higher speeds, safer operation and probably decreases maintenance cost because of the better-balanced unit. Inasmuch as aluminum is non-toxic and its salts are colorless, it is ideal for handling food products.

Reducing the weight of the body is the easiest method for reducing the total weight. As the aluminum body becomes more and more standard, the operator will insist on still further reduction in weight, which will

(*Concluded on p.* 654)

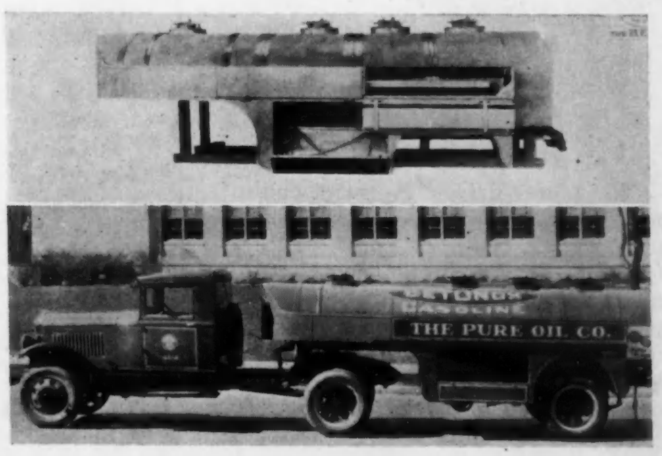
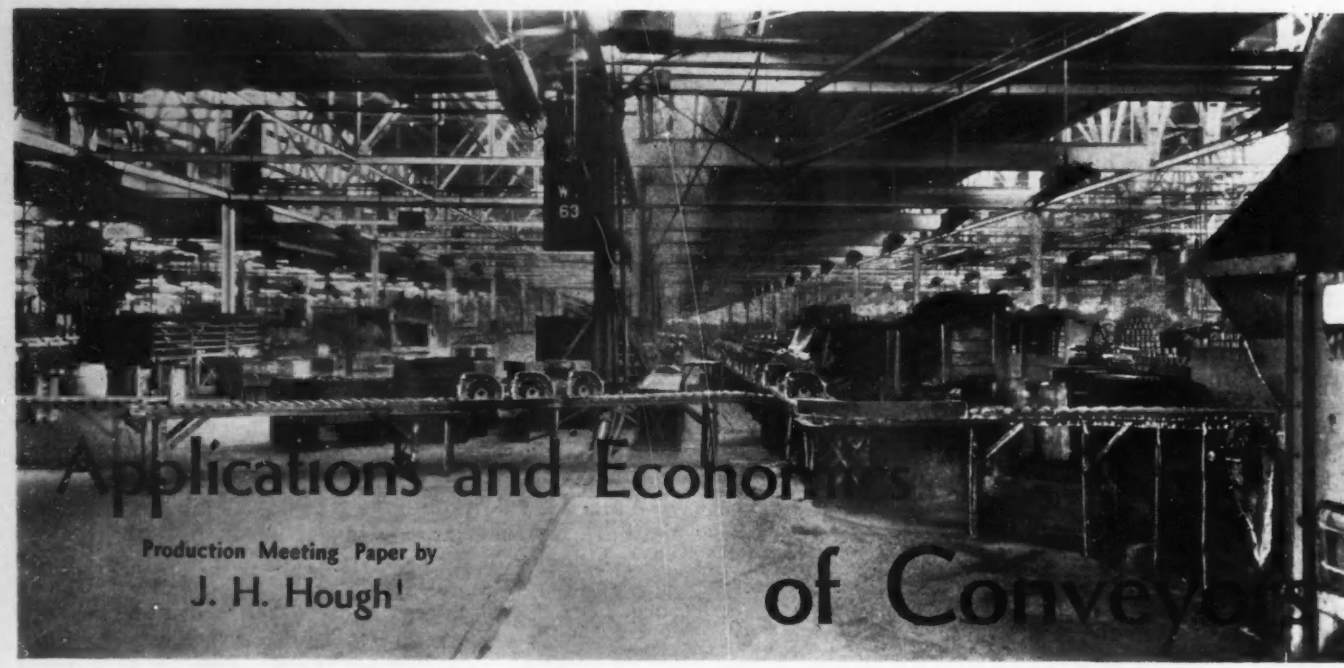


Fig. 8—This Aluminum Tank Is of 900-Gal. Capacity and Replaces a 750-Gal. Steel Tank



Applications and Economics of Conveyors

Production Meeting Paper by

J. H. Hough[1]

ALMOST every type of conveyor may be said to have a field of application at some point in the typical automobile or accessory plant, so great is the variety of the operations performed therein. We can therefore classify the equipment that is available for material handling as follows:

(1) Overhead conveyors
- Chain-trolley conveyors
- Monorail conveyors
- Cranes

(2) General-Type Conveyors
- Gravity roller-conveyors
- Belts
- Apron or pallet conveyors
- Inclined and vertical pusher-bar elevators
- Level, inclined and vertical tray-elevators
- Electric hoists
- Drag chains
- Sheet-metal and roller spirals
- Spiral lifts and descenders

(3) Trucks
- Gasoline and electric tractors with trailers
- Electric lift-trucks
- Hand lift-trucks with skid platforms
- Miscellaneous hand-trucks

Beginning with a classified list of various types of conveying, lifting and lowering devices that are available for factory use, the author outlines the general field of usefulness of each in automotive manufacturing with the aid of illustrations from actual installations. Most of the apparatus described is in use in the industry, but examples from outside are cited as suggestions.

Following this portion of the paper, formulas are presented for estimating the maximum investment that will be profitable in mechanical-handling equipment under any known conditions and the yearly profit that may be realized from the use of such equipment. While developed primarily for the purpose stated, these formulas are said to be applicable to many other cases in which labor-saving equipment or processes are under consideration. Two points emphasized are that overhead should not be omitted, in computing the value of the improved process, from that portion of the direct and indirect labor that is saved, and that increased production frequently has a higher value than normal production.

Tables are given showing approximate costs, for estimating purposes only, of various classes and capacities of material-handling equipment.

Representatives of several manufacturers of material-handling equipment added brief descriptions of conveyors of types not mentioned in the paper, including pusher conveyors, assembly conveyors equipped with roller-bearing wheels, and wide, double-strand overhead conveyors for handling parts being enameled without depositing dust from the track upon them.

The power-driven overhead chain-trolley is one of the most widely used of all types of conveyor, not only in the automotive field but in all industries. Its flexibility in application is the principal reason for its popularity. It can be made almost any length by using a suitable chain and drive. It can be curved in both a horizontal and a vertical plane. It will convey objects of almost any shape by means of hooks or trays of suitable design. The supporting trolley and I-beam can be designed to accommodate any ordinary load. Its principal uses in the automotive plant are for conveying castings from foundry to cleaning room, from cleaning room to machine-shop, and from machine-shop to engine-assembly line and for bringing various completed subassemblies to the main car-assembly line. A large variety of special automatic loading and unloading devices is available for use with this unit. Continuous enameling and paint-drying

[1] Sales manager, Mathews Conveyor Co., Ellwood City, Pa.

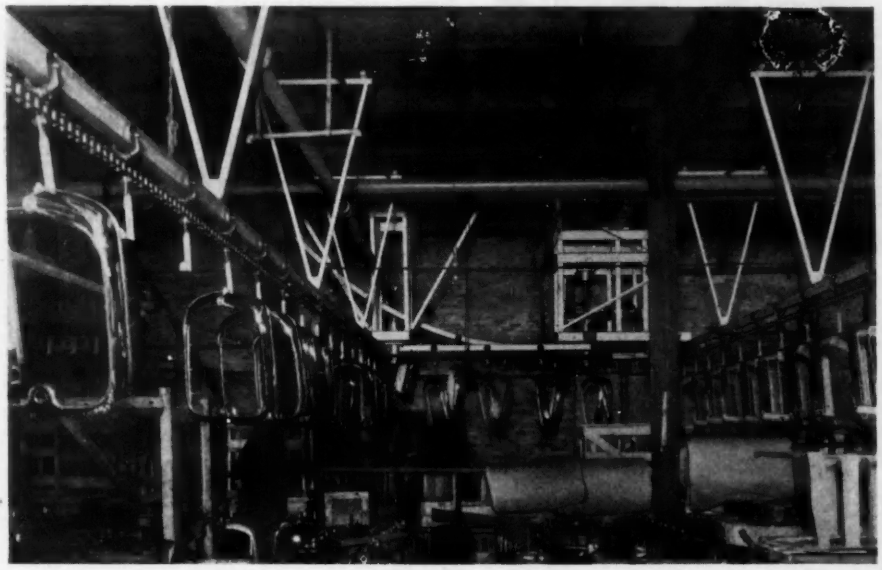


Fig. 1—Overhead Trolley-Chain Conveyor in a Radiator Factory

ovens make use of the trolley chain. Fig. 1 shows such a conveyor at work in a radiator factory.

The monorail conveyor usually consists of a series of level, overhead tracks and switches on which hand or electrically operated trolleys travel, conveying the load. It is common practice to use some form of hoist, such as a chain, electric or pneumatic hoist, to elevate the load. The ordinary application is for the movement of a comparatively heavy object over a fixed level route for short distances. Where the distance is quite great, as from one department of a plant to another, a cab-type hoist is used.

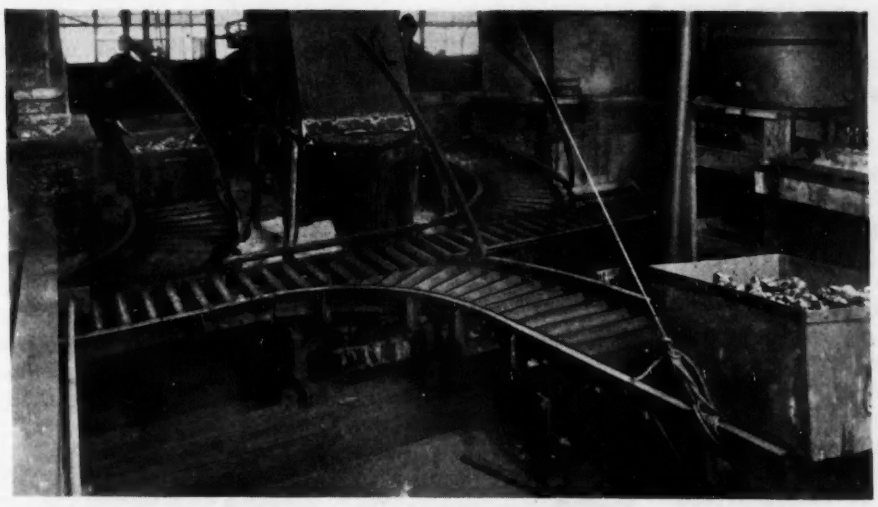


Fig. 2—Roller Conveyor with Switches in a Tool Plant

Drag Chains and Roller Conveyors Are Common

The crane need not be elaborated upon, as its many forms are well known and its field of application is well defined. Often the efficiency of a crane can be improved by using with it short runs of roller conveyor. For example, if a crane is depended upon to lift a part at the conclusion of a certain machine operation, a delay may be caused while the crane is in other service. If the material to be handled is such as will travel on a roller conveyor, it can be run out on a storage line and allowed to remain until the crane is available for lifting it.

Among the general types of conveyor in automotive plants, the drag-chain and roller conveyors are the most commonly used. The drag chain has special applications for assembly lines. It is usually a very slow-speed unit, so that the power required is small and a satisfactory life can be obtained from the chain, even with high friction-loads. Engine, chassis, body and final-assembly lines are usually of this type.

The roller conveyor finds its greatest application in the movement of parts between manufacturing operations: in the foundry, for handling cores and molds; in the cleaning-room, for moving blocks during chipping and through sand-blast and tumbling; in the machine-shop, for moving work from one machine-operation to the next; for moving tote-pans of small parts to the main and sub-assembly lines; for conveying batteries from the charging-room to the car-assembly line; and so on. Roller conveyors are used for the engine-assembly line in some plants, such as for heavy

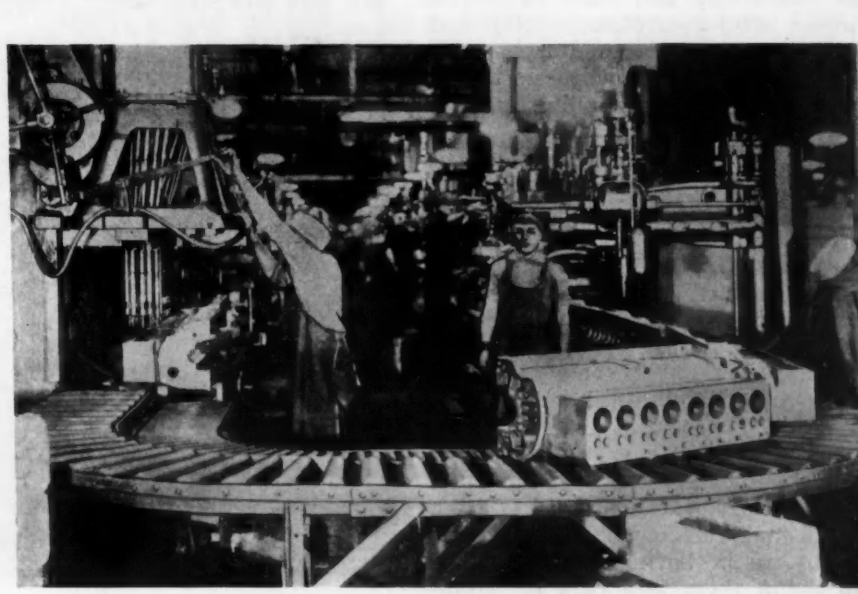


Fig. 3—Roller Conveyor between Machine-Tools

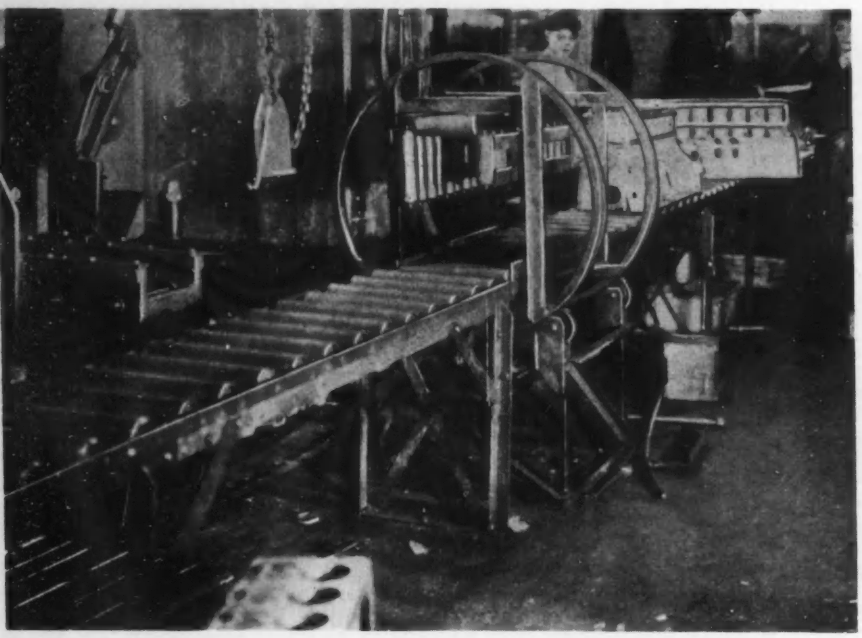


FIG. 4—ROLLER CONVEYOR CONTAINING INVERTING SECTION

tractors. The capacity range of this type of conveyor, which varies from 20 lb. per roller of 1-in. dia. to 5000 lb. per roller of 4-in. dia., makes its field of application wide, throughout all industry. Roller conveyors are to be seen in Figs. 2, 3, and 4, and the lower left corner of Fig. 5, that shown in Fig. 4 including a reversible section for inverting the cylinder-block which it carries.

Belt conveyors have long been used for conveying loose material, but only in recent years have they found wide application for handling parts in manufacturing operations. The automotive-parts plant uses belt conveyors for moving parts either singly or in tote-pans throughout their manufacture and assembly. The belting or carrying surface is varied according to the material to be handled and the conditions and may be canvas, rubber, steel-wire mesh, or flat steel, high-temperature-proofed or sanitary-proofed. A belt conveyor equipped with roller connection is illustrated in Fig. 5.

The apron conveyor, sometimes called a pallet or moving platform, parallels the belt conveyor in its application except that it is used for much heavier work. It is made up of two chains, between and attached to which are steel or wood pallets. These units quite often are used for special sub-assembly work. In some cases the pallets are double headed and provided with skirt plates making a continuous apron as the latter articulates over head and foot sprockets. Such units are used to elevate small parts from quench tanks, to convey hot materials, and to collect borings and turnings and dump them into cars or scrap-presses. The apron conveyor is at times set flush with the floor to permit trucking across it and easy crating of materials on the conveyor.

Devices for Lifting and Lowering

Inclined and vertical pusher-bar elevators have two chains connected at fixed intervals by round cross-bars, the latter suspended above a sheet-metal or roller bed. The unit can be level, inclined upward or downward, or vertical, all in the same conveyor if desired. The material being conveyed is usually automatically received into and discharged from this conveyor. If the elevator is vertical, there is a definite limitation to the variation in maximum and minimum dimensions of packages that can be lifted.

Tray elevators consist of two parallel chains, between which trays of special design are suspended, traveling over head and foot sprockets. These elevators usually form part of a fixed system and are used to receive individual objects, cartons or tote-boxes from a lower line of conveyor and discharge them to a continuing line on an upper floor, or to receive from an upper and discharge to a lower floor. While these units are usually vertical, as seen in Fig. 6, they are at times used in core-ovens and enameling-furnaces and may be installed in a horizontal, inclined or vertical position. Another form of straight-lift elevator is the electric hoist, shown in Fig. 7. This is designed to receive its load automatically from a line of conveyor, elevate it and discharge it automatically to an overhead line, or vice versa. The hoist has the advantage of requiring a floor area only slightly greater than that of the largest object to be conveyed,

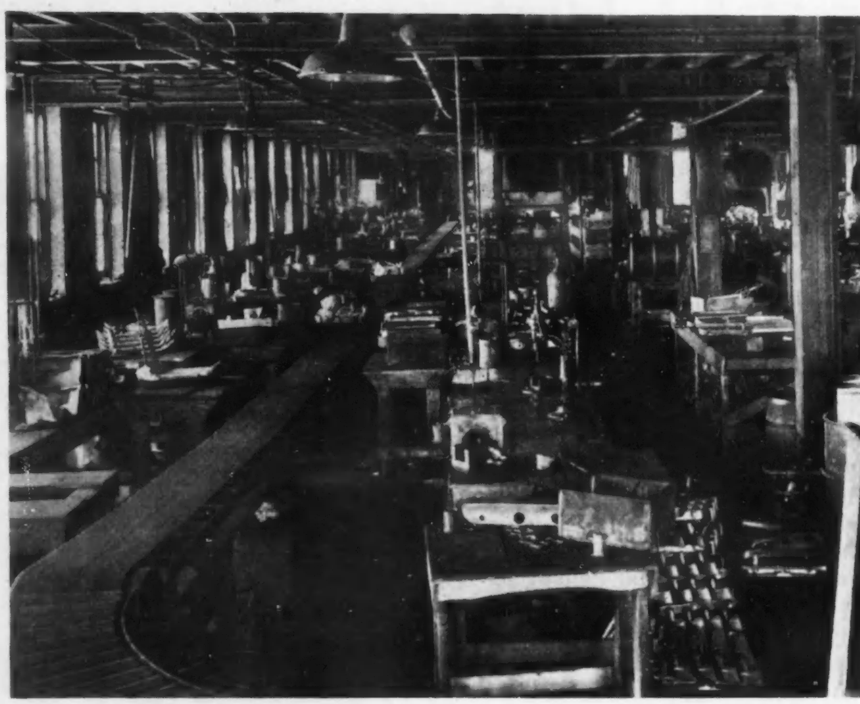


FIG. 5—BELT CONVEYOR, WITH ROLLER CONNECTION, IN A RADIATOR FACTORY

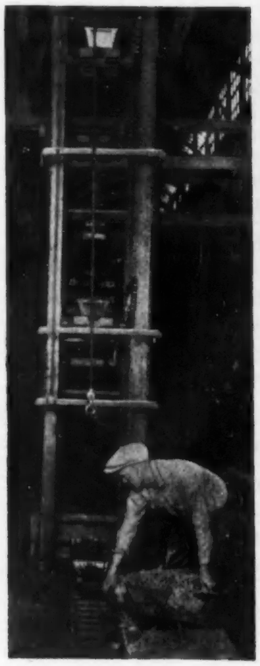


FIG. 6—TRAY ELEVATOR HANDLING VALVES IN TOTE-PANS

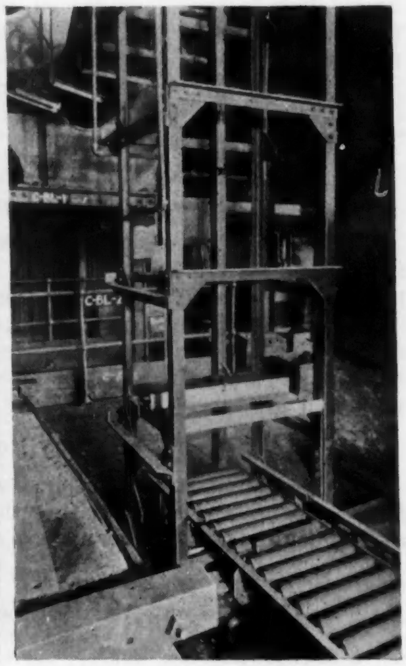


FIG. 7—ELECTRIC-HOIST ELEVATOR IN A TOOL PLANT

while the area required for the tray elevator is about four times the size of the largest object.

For lowering objects between floors, the customary equipment to use is the sheet-metal or ball-bearing-roller spiral. An example of the latter is shown in Fig. 8. Both types of spiral utilize gravity for the operating force, and the free falling of objects is restrained through friction on the tread and outside guard. The sheet-metal spiral is normally used to convey unbreakable objects, although it will convey single objects without damage providing the spiral is not used for storage. With the roller spiral, in which the carrying tread consists of ball-bearing rollers instead of steel plates, the grade required for free starting and stopping can be reduced to a point where the bumping of packages together is not serious, and consequently a spiral of this type can be used for storage purposes.

Another form of power descender is available for handling uniform-sized cylindrical objects. Its principal application thus far has been for handling milk-cans. It consists of a spiral rail supported from a central core or standpipe. Outside of this core is a cylindrical guard of approximately the same diameter as the object being lowered. An automatic feed at the top, properly timed with the revolving spiral, places the object on the rail within the guard at the correct time, and it rides down resting on the rail. Such a unit is shown in operation in Fig. 9.

Portable and Flexible Units

For the handling of bag stock and small cases, a portable unit is available consisting of two parallel pipes with a piece of steel wound in the form of a screw or spiral permanently fastened to the pipe cores. These pipes revolve in opposite directions and the screws cause the objects to be conveyed along between them. This unit can be operated level, or inclined either upward or downward.

Passing from the general types of conveyor we come to the truck classification. Gasoline and electric tractors with their trailers find their greatest application in the movement of materials from one building to another, or where the distance to be covered is comparatively great.

The electric lift-truck is built in a large variety of forms, and its principal function is to convey some form of skid platform on which are piled individual objects or tote-pans of parts. The load is picked up mechanically and deposited in the same manner. The hand lift-truck has the same general function as the electric lift-truck, differing only in being propelled and operated by hand instead of by storage batteries.

Hand trucks are made in a large variety of styles, in many cases being designed to suit the commodity to be handled. The ordinary two-wheel stevedore type

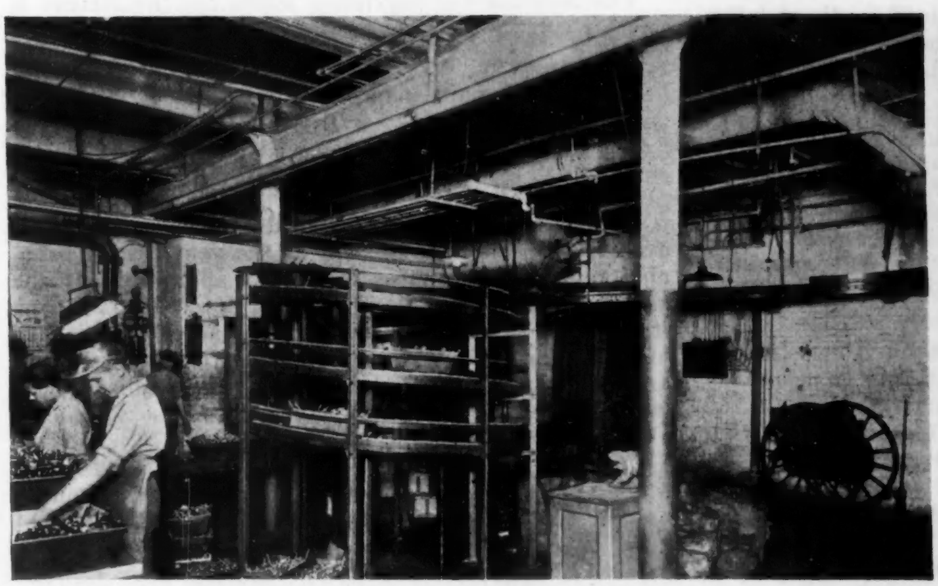


FIG. 8—ROLLER-SPIRAL CHUTE HANDLING TOTE-PANS

FIG. 9—POWER DESCENDER LOWERING MILK-CANS

and the four-wheel swivel-castor type are the most popular.

The following formulas, which are not new and have been used by the material-handling division of the American Society of Mechanical Engineers, have been devised for computing the economies of material-handling equipment. While the formulas have been developed for use in connection with material-handling computations, the fundamental economies as expressed in mathematical form are applicable to most cases in which a difference in labor results from the adoption of a new method, whether it is a material-handling device, a machine-tool or a new process.

Methods and Data for Computing Economy

The whole problem is considered as one of comparative costs. While it has been customary in the past to charge factory burden or factory overhead to the labor-saving devices, it has not been customary to credit the labor-saving device for its portion of overhead saved. This generally is proportional to the reduction in labor, since there is usually a definite relationship between labor and overhead.

In computing costs, the labor to be saved has very frequently been classed as indirect or non-productive labor. As such it is a part of the overhead or burden and should bear no superimposed charge from the other components of the overhead, as that would be pyramiding the charges. But, when comparative costs are desired, the indirect or non-productive labor should be charged with all the component parts of the overhead with the exception of itself. In other words, the reduction in labor, as determined by subtracting the labor used in the new method or device from that used in the old method or device, must be loaded with its share of the burden or overhead, applied to both the productive and the non-productive labor in correct relative proportion.

Two mistakes that have been common in comparing costs have made it difficult to secure accurate comparative results and frequently have obscured the issue. They are: (*a*) the omission of burden or overhead charges on that portion of the direct labor that is saved; and (*b*) the omission of burden charges on indirect labor, even when they are added to direct labor.

In view of these errors, the following rule has been evolved for setting a value upon labor saved by an improved process:

> Whatever valuation is arrived at in cost accounting, as the cost per unit of labor used in production, establishes the value per unit of labor saved by an improved process. For simplicity, no monetary value need be placed upon labor employed in comparative processes except upon the amount of difference in labor required, at the current rate plus burden or its equivalent.

Where the machine-hour system of accounting is in use, the machine-hour rate may cover burden charges only or it may be the total of burden charges and payroll rate of the machine operator, in which case deducting the payroll rate determines the burden charge per hour. Other items of cost should in like manner be at the same rate as for similar items in making up the cost of the product.

In calculating comparative cost, a new item is introduced which rarely becomes a factor in regular cost-accounting but which engineers and economists recognize. This is the monetary value of increased production. Improved methods or devices will reduce the cost of making an article because more are produced in a stated time, which has the same result as reduction in one or more of the items of directly applicable cost. The rule is therefore:

> **In a comparative accounting, increased production has a higher value than normal production.**

The value of increased production through the use of improved mechanical equipment and methods is the minimum where an arbitrarily limited production is required. It reaches its maximum where additional production or performance is necessary, as the usual expedient of enlarging the plant and employing more workmen is thereby avoided.

Calculating the Economies

The foregoing considerations serve as a foundation for the formulas for calculating the economies of labor-saving equipment. Following are the symbols used:

Debit Items

A = Allowance on investment, per cent
B = Allowance for insurance, taxes, etc., per cent
C = Allowance for upkeep, per cent
D = Allowance for depreciation and obsolescence, per cent
E = Total yearly cost of power, supplies, and other items which are consumed, dollars

Credit Items

S = Yearly saving in direct cost of labor, dollars
T = Yearly saving in fixed charges, operating charges or burden, dollars
U = Yearly saving or earning through increased production, dollars

General Items

X = Portion of year during which equipment will be employed, per cent
I = Initial cost of mechanical equipment, dollars
Z = Maximum investment justified by the conditions, dollars
Y = Yearly cost of maintaining mechanical equipment ready for operation, dollars
V = Yearly profit from operation of mechanical equipment, dollars

The formula for maximum allowable investment is

$$Z = \frac{(S + T + U - E)X}{(A + B + C + D)} \tag{1}$$

The cost of maintenance is

$$Y = I(A + B + C + D) \tag{2}$$

The profit from operation is

$$V = (S + T + U - E)X - Y \tag{3}$$

Having in mind that material-handling machinery, even if left idle a large part of the year, would probably require under most conditions approximately the same amount of repairing because of deterioration as it would if in use, no deduction is made for such lack of use in the estimated cost of upkeep, C. If conditions are such that this is not true, use C multiplied by X, in place of C, in the formulas.

Example in Factory Handling Presented

As an example of an application of the formulas, assume that handling of miscellaneous materials about a factory—which has formerly been done by four men receiving \$3.50 per day each, allowing 300 days per year at an annual direct cost of \$4,200—can be done by one man operating an electric-storage-battery industrial-

truck at a direct-labor cost of $1,050 per year, thus effecting a saving at the rate of $3,150 per year in direct-labor cost.

Assume also that, through the greater promptness in moving materials and the more continuous operation of machines, there is an increase in earnings due to increased production that is valued at $650 per year; and that the labor involved, being accounted as non-productive, carries a fixed charge or burden of 10 per cent. In actual practice, the plant operates 240 days per year, or 80 per cent of the time. The various factors, therefore, are estimated as follows:

$A = 6$ per cent	$D = 25$ per cent	$T = \$315$
$B = 4$ per cent	$E = \$450$	$U = \$650$
$C = 20$ per cent	$S = \$3{,}150$	$X = 80$ per cent

The permissible investment then is, according to (1)

$$Z = \frac{(\$3{,}150 + \$315 + \$650 - \$450) \times 0.80}{0.55} = \$5{,}331$$

This indicates that equipment costing any sum below $5,331 will earn some profit above interest on the investment and maintenance.

Assume that an electric-storage-battery industrial-truck will meet the conditions stated and that its cost will be $2,200. Then the yearly cost to maintain the equipment ready for operation, exclusive of labor, will be ascertained by formula (2).

$$Y = I(A + B + C + D) \text{ or } \$2{,}200 \times 0.55 = \$1{,}210$$

Then the profit from operation of the mechanical equipment, according to (3), becomes

$$V = (\$3{,}150 + \$315 + \$650 - \$450) \times 0.80 - \$1{,}210 = \$1{,}722$$

The profit V, or $1,722, represents an annual earning upon the initial investment, above all items of cost, of more than 78 per cent.

If, however, the example selected in handling cargo at a railroad or marine terminal, where the labor is productive labor and subject to all fixed charges as burden, the difference in result will indicate the importance of the factors T and U and the necessity of placing correct values upon them if reliable results are to be obtained.

Terminal Problem Illustrates Distinction

As an example of such an application of the formulas, assume that the amount of handling of miscellaneous cargo at a marine terminal—which has formerly been done by four men receiving $3.50 per day each, allowing 300 days per year at an annual direct-labor cost of $4,200—can be done by one man operating an electric-storage-battery industrial-truck at a direct-labor cost of $1,050 per year, thus effecting a saving of $3,150 per year in direct-labor cost per truck.

Since this labor is productive, it will bear its pro rata share of all fixed charges, estimated at 60 per cent, to be added to the direct-labor cost. This represents a further saving of $1,575 on account of labor. Also assume that, through the greater promptness in unloading and loading vessels, 5 per cent more ships can be accommodated, amounting to the same as 15 days extra use of the pier yearly. Assume the investment in the pier to be $1,000,000, bearing interest and taxes at the rate of 10 per cent per year of 300 working days. Then the 15 days represents 1/20 year and will amount to 0.5 per cent, or $5,000, to be divided say between 20 electric trucks, or $250 per truck per annum.

Applying the formulas as in the previous example, we have for permissible investment

$$Z = \frac{(\$3{,}150 + \$1{,}575 + \$250 - \$450) \times 0.80}{0.55} = \$6{,}582$$

The yearly cost of operation is, as in the previous example,

$$Y = \$2{,}200 \times 0.55 = \$1{,}210$$

The profit above maintenance charges will then be

$$V = (\$3{,}150 + \$1{,}575 + \$250 - \$450) \times 0.80 - \$1{,}210 = \$2{,}410$$

The profit of $2,410 represents an annual earning of nearly 110 per cent upon the investment in this case, in place of the 78 per cent in the previous example, all factors except T, the yearly saving in fixed charges, and U, the yearly saving through increased production, having been upon exactly the same basis.

The following summary shows the relative value of the same device applied to two of the conditions; first, where the labor employed in the work is unproductive as regards producing an article of manufacture, and, second, where the labor used produces the salable commodity, in this case material handling:

	Handling in Factory	Handling in Marine Terminal
Cost of equipment	$2,200	$2,200
Investment justified	5,331	6,582
Yearly maintenance	1,210	1,210
Profit from installation	1,722	2,410
Return on investment	78 per cent	110 per cent

No attempt has been made in the examples given to choose valuations which would approximate reality. All of the items with the exception of T and U have been made uniform for the sake of comparison. The formulas and principles apply whether the equipment is trucks, gravity conveyors, motor-driven conveyor-equipment or all combined.

Rough Costs, for Use in Estimating

Some data on comparative costs of conveyors and elevators of different types and capacities will be of value in order to apply the formulas given in the foregoing. Several variables enter into the cost of every conveyor system, so the rough figures given in Tables 1, 2, and 3 must be considered as approximate and used only for estimating purposes. As an indication of the error that may be made in using average figures without discrimination, one type of roller conveyor with light rollers on wide spacing, priced at $1 per ft., is standard for conveying lumber, while a very high grade of heavy-duty precision-bearing rollers on close centers, priced at $20 per ft., may be required for handling 10-ton bathtub-molds. Length will appreciably affect the price per foot of power conveyors. The number of horizontal and vertical bends in overhead conveyors and the number of switches in monorail conveyors are other examples of variables. In order to have a basis for estimate, let us assume lengths of 100 ft. for horizontal power-conveyors, 30 ft. for inclined and vertical elevators and hoists, 300 ft. for drag-chain conveyors and overhead trolleys, with three 90-deg. curves and three vertical bends and an average speed of 30 to 40 ft. per min. The prices given for the equipment include installation.

The conveyor system is only one of several tools to be considered in setting up a production unit. The basis on which to start is the output required from the

TABLE 1—APPROXIMATE COST OF CONVEYORS OF VARIOUS TYPES

Capacity, Lb. per Ft.	Cost, per Ft.
Roller Conveyors	
300	$3.00
1,000	4.00
4,000	7.00
10,000	25.00
Overhead Chain-Trolley Conveyors, Trolleys 24 In. Apart	
50	6.30
100	6.80
200	7.30
Belt Conveyors, Stitched Canvas 24 In. Wide, 4 Ply, Roller Tread	
100	10.40
200	12.00
Apron Conveyors, Steel Roller-Chains, 24-In.-Wide Channel Pallets	
100	25.40
300	36.80
Drag-Chain Conveyors	
100	19.00
400	26.60
Monorail-Conveyor Rails, Without Trolleys	
Arranged for hand power	1.50
Arranged for electric hoists	2.50
Switches for Monorail Conveyors	
For hand power	$20 each
For electric hoists	$125 each

TABLE 2—APPROXIMATE COST OF ELEVATORS AND SPIRALS

Capacity, Lb. per Package	Cost, per Ft.
Inclined Pusher-Bar Elevators	
100	$28.00
300	41.00
Vertical Tray-Elevators	
100	78.00
300	82.50
Electric-Hoist Elevators	
100	42.00
600	46.30
Spiral Chutes	
One turn of sheet-metal spiral, 6 ft. in dia., 2½-ft. tread, 7-ft. 7-in. vertical drop per turn	$283 each
One turn of tapered-roller spiral, 8 ft. in dia., 24-in. tread, 2-ft. 4-in. vertical lift	$228 each

TABLE 3—APPROXIMATE COST OF TRUCKS AND INDUSTRIAL TRACTORS

Small three-wheel gasoline tractor	$1,250
Large four-wheel gasoline tractor	1,600
Electric elevating truck, with battery, 3 ton[a]	2,430
Electric elevating truck, with battery, 5 ton[a]	3,275
Hand lift-truck	250

[a] Cost of battery charger is extra.

equipment in a definite time. The tool equipment should therefore be decided upon first. The available space should next be given consideration in setting up the production line, and the different types of conveyor come in for careful consideration at this point. If the area is great enough to permit all the machines to be located on one floor, the material-handling problem becomes comparatively easy. It is then simply a matter of moving the parts from one machine to the next, usually by roller conveyor.

When more than one floor or building is involved, the material movement will require a more elaborate system, involving either the overhead chain conveyor, belt, inclined pusher, straight-lift tray-elevator, electric hoist or some form of tractor or truck and freight elevator. It is of course necessary, in deciding on a conveyor system, to know accurately the size and weight of the objects to be conveyed and their physical characteristics, particularly the shape, hardness and temperature. In some departments—as for example the foundry, where molds must be handled—the ability of the object to withstand vibration must be given careful consideration in determining the proper method of handling. The conveyor may be called upon to handle objects at a high temperature in heat-treating departments, and special alloys must be used in the conveyor parts to withstand this.

The size, weight and shape of an object determine whether it should be conveyed as a single piece, grouped on a special hanger or moved in large numbers in tote-boxes. Usually the factor of handling cost must be made secondary to inventory; consequently, it is not always possible to figure on using the type of equipment that will move the material at the lowest cost. The argument is advanced sometimes by a prospective purchaser of equipment that his manufacturing methods are changing so fast that the proposed unit or system may be obsolete in a year and therefore he is warranted in purchasing only the lowest-priced equipment offered, on the theory that it will last at least one year and can then be scrapped. No objection can be offered to this practice if the best equipment can be procured at the lowest price. As a rule, however, the quality is proportionate to the price paid. Moreover, even though the original lineup is maintained for only one year, the equipment can usually be salvaged 100 per cent for use in the new arrangement. Furthermore, it is worth something to the production executive to know that he has some factor of reserve built into his conveyors, for a breakdown in one of them may mean a shut-down in the plant line for some distance in both directions, particularly if the unit happens to be a main assembly-line.

Looking into the Future

No industry is content to sit down and pride itself over past accomplishments. Change is the order of the day; and I will say without hesitancy that conveyors will change, like everything else, and change quite rapidly. As the electric robot is now used to take entire charge of some powerplants and substations, to operate elevators and to control the movement of trains, so we look for the perfection of devices that will receive boxes or cases of almost any variety onto conveyors automatically and deliver them automatically to any desired destination. Special high-temperature material will be employed to give increased life to conveyors operating under high temperatures. Rust-resisting metals will be used more generally, to permit the use of conveyors in water baths and mild acid solutions.

The conveyor engineer is somewhat handicapped in planning for the future because the equipment he designs is seldom built in quantities. An immediate solution is usually called for when a new problem presents itself. That condition prevents the extended research that would without much question result in the production of a more efficient unit. Of course the basic elements of conveyors which lend themselves to some standardization, such as drives, bearings and rollers, are refined and improved almost from day to day.

THE DISCUSSION

CHAIRMAN GORDON LEFEBVRE[2]:—Conveyor manufacturers have done well in keeping pace with the automobile industry, and their sales efforts have been such that men in our factories ask us to install conveyors where their use is not warranted. A formula such as Mr.

[2] Vice-president, Oakland Motor Car Co., Pontiac, Mich.

Hough has outlined will help us to arrive at a sensible decision in doubtful cases.

D. A. BLAIR[3]:—A formula such as the last given in Mr. Hough's paper is of great interest, but I believe that another factor should be added to take into account the floor space occupied by the equipment. If conveyors of two types are equally able to do the work required, the more costly one may be the more economical if it occupies less floor-space. Conveyors usually are installed to eliminate the necessity for plant extensions and additional workmen.

W. V. CASGRAIN[4]:—A few additions might be made to Mr. Hough's classification of conveyors. The side-pusher line might be added to the classification of overhead conveyors. This is used in connection with hand-operated monorail systems as a booster in places where the load cannot well be pushed by hand because of inaccessibility, passing through a drying oven, overcoming an up grade, retarding on a down grade, or under other conditions. The side-pusher line is also used independently of the monorail.

Chain-on-edge conveyors and assembly conveyors might be included under the general type. The chain-on-edge conveyor is used in cases where decided changes in direction are required in a horizontal plane. Used as a direct pusher, the load is carried on dollies or trucks which run astride the chain on a channel track. If it is desirable to be able to add or remove dollies at different points on the line, the side-pusher chain is used and the dolly runs beside the chain.

Assembly conveyors ordinarily consist of a plurality of dollies with flanged wheels running on industrial track and attached to a suitable chain at fixed intervals. The necessary fixtures or cradles to accommodate the parts to be worked on are attached to the dollies. Engines, transmissions, steering-gears and other assemblies are made on conveyors of this type, and it can be used for other purposes. In one case it is used to transport engines from the engine-assembly department to the final-assembly line, and dollies equipped with trays are used in one parts department for collecting orders for small parts from the stock bins and carrying them to the shipping dock.

Power-driven conveyors of both the overhead and floor types are displacing the gravity conveyor in the production machine-shop. The economic advantages are a reduction in inventory and accomplishing the function of a pace setter for the production schedule.

I agree with Mr. Hough that conveyors will be improved rapidly, and the improvements will come to users who recognize the fact that the conveyor manufacturer is unable to do his best without the complete cooperation of his prospective clients. Independent application of correct conveyor principles in a way especially adapted to the individual problem can alone result in an ideal solution of any problem.

Economies from Reducing Friction

J. E. MCBRIDE[5]:—Most of the conveyors formerly used in final-assembly and unit-assembly lines were made on the drag principle, but installations made during the last four or five years in large-production plants are using wheels and axles with roller-bearings. A few years ago, one of the largest automobile companies had four assembly-lines, each 1000 ft. long. Both the conveyor chain and the chassis frame were dragged along, and sometimes the rear axle was almost sawed in two from being dragged along the narrow track. Each line required a 50-hp. motor, and breakdowns were occurring at the rate of about 20 per day. Cutting the conveyor lines in two made some improvement, but the lines were still inefficient.

Eventually, these four lines were replaced with lines embodying roller-bearing wheels. The new conveyor-chains were only about one-fifth as strong as the original chains, and 3-hp. motors, running at one-half load, did the pulling.

Monorail conveyors are used to a limited extent to carry enameled parts through ovens, but it is almost impossible to prevent small particles of dirt from falling from the single track onto such parts as hoods, radiators, and fenders, which must be entirely free from specks. Two-strand overhead conveyors are largely used for enameling purposes in the later installations. The chains, preferably 12-in. pitch with roller-bearing wheels at each joint, are spread 10 to 11 ft. apart and connected by rods or pipes spaced 12 in. apart from which the parts to be enameled are suspended. In this way they are kept from under the tracks.

Rejections on parts such as fenders formerly amounted to as much as 50 per cent in a certain plant. The installation of a two-strand conveyor such as I have described was mainly instrumental in reducing the rejections to about 2 per cent, and probably a large proportion of these rejections is due to imperfect preparation of the metal.

Advantages of Conveyors Listed

Mr. Hough's formula takes into account savings of several sorts to be derived from conveyor installations. While it might be difficult to include all factors of saving in the formula, additional savings should be mentioned in that connection. The following eight reasons for using conveyors in the automobile plants were listed in an article which I prepared for a current periodical[6]:

(1) Floor space is saved. In some cases, work requires only one-quarter to one-tenth of the space that was required without conveyor equipment.

(2) Acting as a pacemaker, the conveyor brings the work to the workman and carries it away, saving much of his effort and automatically spotting an inefficient man.

(3) The conveyor serves as a means of transportation.

(4) The conveyor makes possible a reduction in inventory. When chassis were dried in the natural atmosphere, 10 days might be required during a period of damp weather. A new building was contemplated for increasing the production in one case, but the engineers had the idea that this expenditure might be saved by passing the chassis on a conveyor line through an oven at a temperature of about 200 deg. fahr. Not only was this saving made, but a large area which had formerly been used for drying chassis was made available for other manufacturing uses later.

(5) Conveyors take the control of production away from the workman and put it in the hands of the management. Without conveyors, the workman was not to be blamed if production slowed

[3] Chief engineer, Jervis B. Webb Co., Detroit.
[4] President, Mechanical Handling System, Inc., Detroit.
[5] Vice-president and chief engineer, Palmer-Bee Co., Detroit.
[6] See Houghton's *Black & White*, 1930, p. 17.

up toward the end of the day because of fatigue.

(6) Conveyors contribute to the neat and orderly appearance of a factory. This effect was the one which most impressed a certain manufacturer when he visited the foundry of the Ford Motor Co.

(7) Human effort is saved. It was impossible to operate the curing department of the Detroit plant of the United States Rubber Co. during periods of hot weather because of the heavy loads which the men were required to lift. The application of conveyors in this department in 1916 completely changed that condition. An order was issued in the Goodyear plant in Akron, Ohio, that handling equipment should be provided to make it unnecessary for one man to lift more than 40 lb. at a time. The results were better than had been anticipated, and the limit has been reduced since that time. A great saving accrues to the company, because the men are not tired out and because they work in a happier frame of mind.

(8) Fewer rejections reduce losses. Rejections in many cases have been reduced from 25 per cent to 2 per cent.

Conveyor manufacturers could not make a product of the present quality without the work that has been done by the S.A.E. Standards Committee on alloy steels and roller bearings. This work has enabled manufacturers in other lines to take advantage of the quality and detail design of automobile parts in their products.

CHAIRMAN LEFEBVRE:—I can recall several instances in which conveyors have been installed to improve the quality of the product, which is a purpose on which all manufacturers are intent today as never before. An illustration is the handling of machine parts which cannot be transported in tote-pans without injury. We have installed conveyors that prevent such parts from touching each other in transportation, thereby avoiding nicking and abrading the parts.

Aluminum Alloys Used in Commercial Vehicles

(*Concluded from p. 645*)

TABLE 9—WEIGHT SAVING ON A SPECIAL VEHICLE

	Steel, Lb.	Aluminum, Lb.	Saving, Lb.
Tank, complete, 750-gal. capacity	3,345	1,935	1,410
Trailer, complete	2,110	1,600	510
Total	5,455	3,535	1,920

	Lb.
Payload for each tank,	
750 gal. of gasoline at 6.2 lb. per gal.	4,650
Two 55-gal. drums of oil at 465 lb. each	930
Total payload for each tank	5,580
Gross load of steel unit	11,035
Gross load of aluminum unit	9,115
Saving in gross load	1,920

necessitate lightening the chassis and cab. In a few scattered instances, this need has been felt already, and several trailers and semi-trailers have been built. It has also resulted that truck manufacturers use aluminum sheets for cabs and, in many instances, radiators and engine parts. It will certainly bring about the demand for aluminum chassis-frames, wheels, and axle housings, and it is a certainty that the next few years will see remarkable developments along these lines.

That reduction of dead weight is economical is evidenced by the rapid growth of the aluminum-body industry, and the magnitude that this industry will reach within the next few years is probably beyond the most optimistic predictions.

Practical Tractive-Ability Methods

By Austin M. Wolf[1]

Transportation Meeting Paper

THE TRACTIVE ability of a motor-vehicle, as stated by the author, is the measure of its power to overcome outside resistances to its translation, based on the tangential force exerted by the driving wheels at their points of contact with the road. The propelling force is derived from the engine. To compute the "tangential force" of the foregoing definition it is engine torque that interests us rather than the horsepower, he states. If the horsepower is given, it can be converted into torque.

After analyzing this point mathematically, the author discusses typical tractive-factors of modern motor-trucks so that he is enabled to develop an economic factor mathematically and thus be prepared to discuss tractive resistance as opposed to tractive effort. Air resistance is considered in detail as a particularly important factor concerning motorcoaches, and the author's points are backed up by diagrams and charts as well as by numerous tables of statistical and computed data.

In an Appendix, other tabulated data are presented which show the results obtained with a testing machine in which the conditions of a tire rolling on a hard smooth surface are reproduced and rolling resistance is measured correctly.

IN PRESENTING the subject of practical methods for determining and comparing tractive ability, I may say that the underlying principles of tractive ability could have been no mystery to primitive man, who, no doubt, utilized them unknowingly. In carrying a load, dragging it on a pole, or substituting "motive power" in the form of a beast of burden for the human powerplant, primitive man realized the varying resistances of different terrain, the added exertion when climbing a hill, the increased "advantage" realized by short steps and variations due to differently shaped pole-ends. It is not to the credit of the present generation that elaborate formulas have taken these principles into account.

The French Minister of War ordered experiments made in 1837 and 1838 to cover tractive resistances of gun carriages, freight cars, artillery wagons, freight wagons, stage-coaches, carriages and wagons—the last three being without springs—on miscellaneous surfaces. Prior to 1894, Ellwood Haynes towed a bicycle about the streets of Kokomo, Ind., to get draft readings, and these figured prominently in his estimate of power requirements for locomotion on roads. The tractive-ability formulas for locomotives antedated the automobile era, and the same essential factors are found therein.

An elaborate paper could be written on this subject to cover fully all phases thereof, but I shall attempt to present only a simple basis whereon operators can compare different vehicles and realize the influence of engine output, geat ratio and constructions affecting weight; also, the various resistances encountered by the vehicle.

Motor-Vehicle Tractive-Ability

The tractive ability of motor-vehicles is the measure of its power to overcome outside resistances to its translation, based on the tangential force exerted by the driving wheels at their points of contact with the road. The propelling force is derived from the engine. To compute the "tangential force" of the foregoing definition, it is engine torque that interests us rather than the horsepower. If the horsepower is given, it can be converted into torque by the formula:

$$T \text{ (in-lb.)} = \frac{\text{Hp.} \times 33{,}000 \times 12}{2\pi \times \text{R.P.M.}} = \frac{\text{Hp.} \times 63{,}025}{\text{R.P.M.}} \qquad (1)$$

Some tabulations give the horsepower at maximum torque. To make the conversion into torque, Table 11 of the Appendix may be consulted. Many formulas exist whereby cylinder size and number, piston speed and the like can be converted into torque. Inasmuch as they usually presuppose certain fixed conditions which can hardly cope with variations of design and application, it seems absurd to attempt to use them today when all engine manufacturers furnish torque curves or figures, which figures are actual and not hypothetical. The axle gear-ratio is known and also the tire size. Since it is the rolling radius *OA* of the tire as shown in Fig. 1 that concerns us, we can obtain this by measuring its standing height or consult the figures for it given in Tables 1 and 2.

A wheel is a continuous lever and the radius *OA* is one "lever" in the wheel, running from shaft *O* to the point of tire contact with the road. Torque impressed on shaft *O* in the direction of the arrow tends to rotate the wheel counter-clockwise; but, assuming sufficient adhesion between the tire and the road, such rotation by itself is impossible. Momentarily, point *A* becomes a fulcrum and point *O* presses forward. The axle shaft therefore exerts a pressure that propels the vehicle through the intermediary of the shaft or wheel bearings, axle shell and the radius-rods or springs.

The torque impressed on shaft *O* in high gear is theoretically equal to the engine torque multiplied by the axle reduction. Should any of the indirect transmission ratios be used, this value is again increased by multiplying by the ratios of the transmission gears.

[1] M.S.A.E.—Automotive consulting engineer, New York City.

TABLE 1—DATA ON HIGH-PRESSURE MOTOR-TRUCK TIRES[a]

Tire Size, In.	No. of Plies	Load Capacity, Lb.	Inflation Pressure, Lb. per Sq. In.	Rim Size, In.	Dual Spacing, In.	Over-All Diameter, In.	Cross-Section Diameter, In.	Maximum Deflected Cross-Section Diameter, In.	Rolling Radius, In.	Weight, Lb. Tire	Weight, Lb. Tube Medium	Weight, Lb. Tube Heavy	Weight, Lb. Flap	Weight, Lb. Total[c]
30 x 5 T. T.	6	1,575	75	5	7¼	32.2	5.9	6.70	15.25	33.5	2.8[b]	....	1.1	37.4
30 x 5 H. D.	8	1,700	80	5	7¼	32.5	6.0	6.85	15.71	39.9	3.3[b]	....	1.3	44.5
33 x 5 H. D.	8	1,700	80	4½		35.5	5.8	6.85	16.95	42.9	3.4[b]	....	1.0	47.3
34 x 5 H. D.	8	1,950	80	5	7¼	36.6	5.9	6.85	17.70	45.8	3.5[b]	....	1.5	50.8
35 x 5 H. D.	8	1,950	80	4½		37.6	5.8	6.85	18.01	45.9	3.6[b]	....	1.1	50.6
32 x 6 T. T.	8	1,950	80	5	7¾	33.4	6.4	7.05	15.88					
				6	9	33.4	6.5	7.15	16.02	47.6	5.1[b]	....	1.1	53.8
32 x 6 H. D.	10	2,200	90	5		34.3	6.8	7.45	16.52					
				6	9[d]	34.5	6.9	7.55	16.72	66.5	7.9	8.2	1.7	76.4
36 x 6 H. D.	10	2,500	90	5		38.4	6.8	7.45	18.39					
				6	9[d]	38.6	6.9	7.55	18.70	75.8	8.8	9.2	2.0	87.0
34 x 7 H. D.	10	2,800	100	6		36.6	7.7	8.40	17.50					
				7	10[d]	36.6	8.0	8.70	17.66	84.1	11.2	11.4	2.9	98.4
38 x 7 H. D.	10	3,200	100	6		40.6	7.7	8.40	19.39					
				7	10[d]	40.6	8.0	8.70	19.67	95.5	12.6	12.8	3.4	111.7
36 x 8 H. D.	12	3,600	110	7		38.6	8.8	9.70	18.45					
				8	11½[d]	38.6	9.1	10.00	18.70	120.3	14.9	15.1	3.3	138.7
40 x 8 H. D.	12	4,000	110	7		42.6	8.8	9.70	20.38					
				8	11½	42.7	9.1	10.00	20.71	134.7	16.4	16.8	4.0	155.5
38 x 9 H. D.	14	4,500	120	8	11½[e]	41.2	10.2	11.40	19.61					
				9–10	12¾	41.2	10.6	11.60	19.88	163.5	18.3	18.4	3.3	185.2
42 x 9 H. D.	14	5,000	120	8	11½[e]	45.3	10.2	11.40	21.60					
				9–10	12¾	45.3	10.5	11.60	21.86	183.7	20.2	20.4	4.0	208.1
40 x 10 H. D.	16	5,500	130	9–10	....	43.9	11.4	12.35	21.17	227.2	23.1	23.6	4.7	255.5
44 x 10 H. D.	16	6,000	130	9–10	....	48.0	11.3	12.35	23.14	253.8	26.0	26.7	5.7	286.2

[a] Data furnished by Goodyear Tire & Rubber Co.
[b] Tubes are light weight and not medium.
[c] Total weight includes heaviest tube.
[d] Not permitted as original equipment.
[e] Permitted but not recommended.

The transmission of torque from the engine flywheel to the rear wheels is always accompanied by a loss due to the inefficiency of the various parts comprising the entire power-conveying line. The general over-all efficiency in direct drive is usually assumed to be 85 per cent and is fairly accurate, judging by various tests that have been made. While the different axle manufacturers may claim a greater efficiency for one form of final drive over another, we can well keep out of this controversy and use the above figure since the formula to be given is only a means of measurement whereby different vehicles can be compared on a common basis. While slight efficiency-differences might exist, they are easily outweighed by variables that no formula could possibly cover. We will also assume that in indirect gear the over-all efficiency is 88.24 per cent.

Knowing the torque on shaft O, the force exerted at point A to give the tractive effort will be equal to the torque divided by the length OA. If the engine torque is given in inch pounds, OA also should be in inches. Otherwise, "feet" must appear in both quantities. The tractive effort is therefore:

$$TE = \frac{T \times R \times e}{r} \text{ (in direct drive)} \qquad (2)$$

or

$$\frac{T \times R_1 \times e_1}{r} \text{ (going through transmission gears)} \qquad (3)$$

where

TE = tractive effort
T = engine torque, in inch-pounds
R = axle ratio
R_1 = transmission reduction-ratio
e = 85 per cent direct-gear over-all drive efficiency
e_1 = 75 per cent indirect-gear over-all drive efficiency
r = rolling radius of the tire, expressed in inches

It will be noted that we have considered the entire propulsion as though it were derived from one wheel. While actually two, four or more wheels may be driving, the sum total is always the same as if we considered one wheel doing all the work; it makes no difference as to figuring tractive effort.

The subject of slippage would be interesting to investigate as the individual effort, loading, contact area, tread design and the coefficient of friction between the tires and the road surface would be vital factors. Hence the use, frequently, of four driving wheels in four or six-wheeled vehicles for particular traction or loading conditions. However, this is outside of the scope of the present paper. It would bear study, particularly in some of our high-powered passenger-cars, where it is easy enough under certain conditions to spin the driving wheels in low gear. The four-wheel-drive passenger-car is sure to come, gaging the upward trend in speed made possible by modern highway-systems.

Formulas (2) and (3) give the tractive effort of a vehicle, and probably no two vehicles of different make would be found to be alike because of their varying characteristics; hence, direct comparisons would be impossible. A common ground would be the tractive effort per pound of gross vehicle-weight; that is, of chassis, body and load, which method was introduced by C. T. Myers in his paper entitled Motor Capacity for Motor-Trucks[2]. This tractive factor, TF, is the same as in formulas (2) or (3) with the gross weight, W, in the denominator, or:

$$TF = \frac{T \times R \times e}{r \times W} \text{ (in direct gear)} \qquad (4)$$

or

$$= \frac{T \times R \times R_1 \times e_1}{r \times W} \text{ (in indirect gear)} \qquad (5)$$

To illustrate the use of the formula (5), let us take a motorcoach having an engine giving a maximum torque of 4920 in-lb., a 4.8 to 1 rear-axle ratio, 9.00—20-in. tires the rolling radius of which is 18.2 in., and a gross weight of 18,000 lb. Then

$$TF = \frac{4920 \times 4.8 \times 0.85}{18.2 \times 18{,}000} = 0.061 \text{ (in direct drive)}$$

If a 6 to 1 axle-ratio were used, then $TF = 0.077$. This gives a higher performance-figure but, naturally, the vehicle could not attain the road speed that the other ratio would allow, assuming an equal number of

[2] See S.A.E. TRANSACTIONS, 1913, vol. 8, part 1, p. 103.

revolutions per minute of the engine. Greater engine-torque would also increase the performance figure, but we know that there is a limit to engine size in view of economy and weight; the minute we increase it, we get a heavier vehicle and the greater *W* in the denominator partly cancels out the extra torque in the numerator.

An analysis showing the relationship and influence of one of these factors over the other would make an interesting subject for a future paper. If increased torque could be obtained without increased weight through greater engine-efficiency, the gain would be desirable and usable. This is taking place today and the question remains whether the heavier stresses set up in the power line really require heavier clutches, transmissions, propeller and axle shafts. It seems that the parts makers realize this condition and, occasionally, a heavier unit is brought out to replace the former model.

Motorcoach Design Now Evolutionary

Motorcoach design is in a transient, evolutionary stage. The engines of today are of greater displacement than those of a few years ago and they will continue to gain in size, as the unattainable ideal is to give to the motorcoach the performance ability of the passenger-car. However, considerations of economy preclude the possibility of such a vehicle or even an approach thereto. Economy will be discussed later, in connection with motor-trucks.

Increased power-transmitting efficiency would help, but it is doubtful if much improvement can be made along this line. Whatever the combination of gearing and power transmission is that might be used, there are bound to be losses. In fact, we see efficiency sacrificed for comfort and the elimination of shock and jar as in the gasoline-electric drive. For a particular field, this compromise is justifiable.

The smaller the rolling radius of the wheel is, the higher would be the tractive-factor value. But as there are many other phases that dictate the wheel diameter, and as such variations can be compensated for by the gear ratio this item needs no consideration other than its being a necessary element in the formula. Weight is a most important item; the smaller the weight is, the greater will be the tractive factor. Intensive study is being made on aluminum bodies in the motor-truck and in the motorcoach fields, and the benefits will be discussed more fully further on. It is the same incentive that has caused the Pullman Company and street-car builders to look into the matter of weight reduction through the use of light alloys.

In the same manner that motorcoach engines have increased in size, so also has the motor-truck engine. It is interesting to review some of the opinions of somewhat more than 15 years ago in which engines of that day were considered greatly over-sized and uneconomical. For example, the following quotations of that time are given, as follows:

> It is possible to decrease by at least 33⅓ per cent the volumetric displacement of the average truck engine of today" (1912).
>
> I think it is pretty well conceded that, on the electric truck, the life of the tire, bearings, springs, frames and so on is considerably longer than on a gasoline truck of corresponding capacity operated in similar service. There is no doubt that this is due principally to the one thing, speed. If gasoline-truck manufacturers come to a full realization of this fact and get right down to the small engine with a big range of gear ratios, they are going to give the electric-truck manufacturers a run for their money even in their own field."
>
> I believe you cannot drive a 5-ton truck over the

TABLE 2—DATA ON MOTOR-TRUCK AND MOTORCOACH BALLOON TIRES[f]

Tire Size, In.	No. of Plies	Load Capacity, Lb.	Inflation Pressure, Lb. per Sq. In.	Rim Size, In.	Dual Spacing: Tire and Rim Association Standard, Cannot Oversize	Dual Spacing: Tire and Rim Association Standard, Permits Oversize	Dual Spacing: Obsolete, Not for Original Equipment, Cannot Oversize	Over-All Diameter, In.	Cross-Section Diameter, In.	Maximum Deflected Cross-Section Diameter, In.	Rolling Radius, In.	Weight, Lb.: Tire	Weight, Lb.: Tube, Medium	Weight, Lb.: Tube, Heavy	Weight, Lb.: Flap	Weight, Lb.: Total[g]
5.50-20	6	1,225	40	5	....	7¼	....	32.1	6.05	6.95	15.19	27.4	....	3.4	1.0	31.8
6.00-20	6	1,400	45	5	7¼	7¾	....	32.6	6.25	7.30	15.42	31.1	....	4.1	1.4	36.6
6.50-20	6	1,650	50	5	7¾	8¼	....	33.8	6.65	7.75	15.98	38.8	....	4.4	1.4	44.6
				5	8¼	....	....	34.9	7.20	8.15	....	....	....	....	..	....
7.00-20	8	1,900	55	6	....	9	8¼ & 8 13/16	35.0	7.30	8.20	16.49	58.2	6.9	....	1.5	66.6
				6	9	....	8 13/16	35.8	7.75	8.90	....	....	....	....	..	....
7.50-20	8	2,100	55	7	....	10	....	35.8	7.90	9.00	16.90	59.9	9.7	10.4	2.9	73.2
8.25-20	10	2,550	60	7	10	10½	9¾	37.3	8.60	9.70	17.70	85.3	10.8	12.0	2.9	100.2
				7	10½	....	....	38.8	9.30	10.50	....	....	....	....	..	....
9.00-20	10	3,250	65	8	....	11½	....	38.9	9.60	10.60	18.20	100.1	14.9	14.3	3.3	118.3
9.75-20	12	3,900	70	8	11½	12	....	40.2	10.10	11.35	18.87	128.1	18.0	16.6	3.3	149.4
				8	12	....	....	41.4	10.50	11.80	18.76	....	....	....	..	....
10.50-20	12	4,700	75	9–10	12¾	13¾[h]	....	41.4	10.90	12.00	19.55	146.1	22.3	21.2	5.1	173.5
11.25-20	14	5,450	80	9–10	....	13¾[h]	....	43.1	11.50	12.80	20.23	182.6	....	26.1	5.1	213.8
				9–10	13¾[h]	....	....	45.0	12.40	13.70	21.26	....	....	....	..	....
12.00-20	14	6,250	85	11	14¼[h]	15[h]	....	44.9	12.85	14.10	21.21	201.9	....	30.6	5.9	238.4
12.75-20	16	7,200	90	11	15[h]	16[h]	....	46.2	13.40	14.70	21.63	244.1	....	35.0	5.9	285.0
13.50-20	16	8,200	95	11	16[h]	....	....	47.3	14.05	15.25	22.11	268.8	....	37.9	5.9	312.6
8.25-22	10	2,800	60	7	10	10½	9¾	39.4	8.60	9.70	18.72	90.5	11.5	12.6	3.2	106.3
				7	10½	....	....	40.8	9.30	10.50	....	....	....	....	..	....
9.00-22	10	3,500	65	8	....	11½	....	40.9	9.60	10.60	19.16	106.3	15.7	15.5	3.7	125.7
9.75-22	12	4,200	70	8	11½	12	....	42.1	10.10	11.35	19.84	135.8	18.6	17.6	3.7	158.1
				8	12	....	....	43.4	10.50	11.80	19.73	....	....	....	..	....
10.50-22	12	5,000	75	9–10	12¾	....	....	43.5	10.90	12.00	20.50	152.0	....	23.3	5.7	181.0
				6	9	....	8 13/16	39.8	7.75	8.90	....	....	....	....	..	....
7.50-24	8	2,400	55	7	....	10	....	39.9	7.90	9.00	18.84	69.0	....	11.7	3.4	84.1
8.25-24	10	2,950	60	7	10	10½	9¾	41.4	8.60	9.70	19.64	95.3	....	13.6	3.4	112.3
				7	10½	....	....	42.8	9.30	10.50	....	....	....	....	..	....
9.00-24	10	3,650	65	8	....	11½	....	42.9	9.60	10.60	20.12	111.1	....	16.1	4.0	131.2
9.75-24	12	4,400	70	8	11½	12	....	44.2	10.10	11.35	20.82	140.6	....	18.7	4.0	163.3
				8	12	....	....	45.5	10.50	11.80	20.80	....	....	....	..	....
10.50-24	12	5,200	75	9–10	12¾	13¾[h]	....	45.6	10.90	12.00	21.44	156.2	20.3	....	6.2	182.7
11.25-24	14	6,050	80	9–10	....	13¾[h]	....	47.1	11.50	12.80	22.13	206.7	....	29.7	6.2	242.6
				9–10	13¾[h]	....	....	48.9	12.40	13.70	22.92	....	....	....	..	....
12.00-24	14	6,950	85	11	14¼[h]	15[h]	....	48.8	12.85	14.10	22.95	229.8	....	34.1	7.2	271.1
12.75-24	16	8,000	90	11	15[h]	16[h]	....	50.3	13.40	14.70	23.57	277.5	....	38.6	7.2	323.3
13.50-24	16	9,100	95	11	16[h]	....	....	51.3	14.05	15.25	24.17	296.0	....	41.6	7.2	344.8

[f] Data furnished by Goodyear Tire & Rubber Co.
[g] Total weight includes heaviest tube.
[h] Tentative spacings.

TABLE 3—TRACTIVE FACTORS OF A TYPICAL LINE OF MODERN MOTOR-TRUCKS

Make	Model	Gross Weight, Lb.	Tire Size, In.	Engine	No. of Cylinders and Size, In.	Maximum Torque In-Lb.	Gear Ratio High	Gear Ratio Low	Tractive Factor High	Tractive Factor Low	*TF* (In High) 1912
					1-Ton Trucks						
Atterbury	A-6	6,915	30x5	Lyc WRG	Six (2⅞x4¾)	1,446	6.83	43.5	0.077	0.434	
Brockway	60	6,000	30x5	Con	Six (3⅜x4)	1,644	5.59	19.8	0.083	0.259	
Brockway	65	6,500	30x5	Con	Six (3⅜x4⅝)	1,788	5.12	21.3	0.076	0.280	
Day Elder	60	6,000	6.50-20	Con 25A	Six (3⅜x4)	1,644	5.60	36.3	0.082	0.466	
Diamond T	200	6,500	30x5	Bud H199	Four (3¾x4½)	1,500	6.30	40.3	0.079	0.444	
Diamond T	215	6,500	30x5	Bud J214	Six (3⅜x4)	1,620	5.40	29.2	0.073	0.347	
Federal	D	7,500	32x6	Con W10	Four (3⅞x4¼)	1,440	6.38	40.8	0.065	0.367	
Federal	E-6	7,500	32x6	Con 17E	Six (3⅜x4)	1,644	5.40	34.6	0.063	0.355	
Fisher	10A	7,500	30x5	Con 17E	Six (3⅜x4)	1,644	5.83	37.4	0.069	0.392	
General Motors	T 17-1703	6,000	7.00-20	Pontiac	Six (3$\frac{5}{16}$x3⅞)	1,476	4.83	16.0	0.061	0.179	
Gramm-Bernstein	10	7,000	30x5	Lyc CT	Four (3¾x5)	1,536	4.86	20.8	0.058	0.218	
Indiana	60	6,000	30x5	Con	Six (3⅜x4)	1,644	5.59	19.8	0.083	0.260	
Indiana	200	6,500	32x6	Wis	Six (3¼x4¼)	1,740	5.12	21.3	0.073	0.266	
Indiana	64	6,500	30x5	Con	Six (3⅜x4⅝)	1,788	5.12	21.3	0.076	0.280	
Internat'l Harves.	6 Sp. Spec.	6,213	30x5	Wau XA	Four (3½x4½)	1,356	5.29	72.4	0.062	0.665[i]	
Kenworth	70	7,000	30x5	Con 18E	Six (3⅜x4)	1,644	5.40	34.6	0.069	0.388	
Kleiber	51	6,000	30x5	Con 18E	Six (3⅜x4)	1,644	4.80	28.3	0.071	0.370	
LaFrance-Republic	A-1	6,000	32x6	Lyc WRG	Six (2⅞x4¾)	1,446	5.86	36.1	0.075	0.407	
Stewart	30-X	6,305	6.50-20	Lyc WSG	Six (2⅞x4¾)	1,446	5.60	35.8	0.068	0.384	
Studebaker	S30	6,065	30x5	Own	Six (3¼x4⅛)	1,644	4.64	13.8	0.068	0.178	
White	15B	7,500	30x5	Own GKA	Four (3¾x5⅛)	1,416	5.36	18.6	0.055	0.168	
White	60	8,000	30x5	Own 2A	Six (3½x4½)	1,848	4.73	17.8	0.059	0.191	
Average									0.0702		0.0788
					2-Ton Trucks						
Acme	47	10,200	32x6	Con 16C	Six (3⅜x4⅝)	1,788	6.80	22.4	0.063	0.184	
Atterbury	G	9,950	32x6	Lyc 4SL	Six (3¼x4½)	1,740	6.80	34.0	0.066	0.278	
Autocar	A	12,000	34x7	Own	Six (4x4¾)	2,880	5.22	27.3	0.060	0.278	
Autocar	D	15,000	34x7	Own	Six (4x4¾)	2,880	6.30	33.7	0.058	0.275	
Brockway	S-31	12,000	S34x8	Wis	Four (4x5)	1,920	7.25	38.8	0.058	0.275	
Brockway	120	12,000	32x6	Con	Six (4x4⅛)	2,352	5.85	31.3	0.061	0.286	
Day-Elder	110	11,000	7.00-20	Con 16C	Six (3⅜x4⅝)	1,788	7.25	47.8	0.061	0.354	
Diamond T	303	11,000	32x6	Her WXB	Six (3¾x4½)	2,304	5.66	33.1	0.063	0.325	
Federal	A6	10,500	32x6	Con 16C	Six (3⅜x4⅝)	1,788	6.38	38.5	0.058	0.306	
General Motors	T30-3201	10,000	30x5	Buick	Six (3$\frac{7}{16}$x4⅝)	2,220	5.63	28.6	0.068	0.303	
Indiana	140	14,000	32x6	Con 30B	Six (4x4⅛)	2,352	6.66	35.3	0.059	0.278	
Indiana	400	12,500	32x6	Wis Y	Six (3⅜x5)	2,230	6.37	34.2	0.060	0.286	
Indiana	111XW	10,000	32x6	Her OX	Four (4x5)	1,860	6.57	35.2	0.065	0.306	
Internat'l Harves.	SD-44	10,295	32x6	Lyc CT	Four (3¾x5)	1,536	6.87	40.6	0.054	0.284	
Internat'l Harves.	SD-46	10,355	32x6	Lyc 4SL	Six (3¼x4½)	1,740	6.87	40.6	0.061	0.320	
Internat'l Harves.	A-4	13,070	32x6	Own FBB	Six (3⅝x4½)	2,160	6.50	47.8	0.057	0.370	
Maccar	40	12,400	32x6	Bud HS-6	Six (3⅜x4½)	1,716	6.16	33.0	0.045	0.214	
Moreland	RR7	9,300	32x6	Con 16C	Six (3⅜x4⅝)	1,788	5.83	32.9	0.059	0.296	
Schacht	20	9,500	7.50-20	Con 16C	Six (3⅜x4⅝)	1,788	5.83	31.2	0.055	0.260	
Sterling	DB9-64	9,000	34x7	Con 16C	Six (3⅜x4⅝)	1,788	5.82	29.1	0.056	0.246	
Stewart	29XS	10,235	32x6	Lyc ASA	Six (3⅝x4½)	2,172	6.37	44.4	0.071	0.440	
Studebaker	S50	9,410	6.50-20	Own	Six (3¼x4⅛)	1,644	5.83	37.4	0.054	0.306	
Average									0.0596		0.0664
					3-Ton Trucks						
Autocar	H	19,000	34x7	Own	Four (4½x5½)	2,616	7.67	48.6	0.051	0.283	
Autocar	SH	19,000	34x7	Own	Six (4¼x4¾)	3,252	6.95	44.0	0.057	0.320	
Available	T-34	19,000	36x8	Wau SRL	Six (4⅜x5⅛)	3,624	8.50	80.7	0.074	0.616	
Brockway	KW	18,000	34x7	Wis	Six (4x5)	3,180	6.80	36.3	0.058	0.272	
Brockway	190	19,000	34x7	Con	Six (4⅛x4¾)	2,832	7.75	78.6	0.056	0.497	
Day-Elder	160	16,000	9.00-20	Con 18R	Six (4x4½)	2,544	6.75	36.1	0.050	0.237	
Diamond T	602	19,000	36x8	Her YXC	Six (4⅜x4¾)	3,360	8.50	44.2	0.068	0.313	
Fageol	340	18,500	36x6	Wau CU	Four (4⅜x5¾)	2,700	5.19	93.3	0.034	0.545	
Fageol	365	15,500	36x6	Wau KU	Six (4¼x4¾)	2,976	7.75	41.5	0.067	0.319	
Fageol	370	18,500	36x6	Wau SRL	Six (4⅜x5⅛)	3,624	5.19	93.3	0.046	0.732	
Federal	U6	19,000	34x7	Con 18R	Six (4x4½)	2,544	6.80	64.6	0.044	0.367	
Fisher-Stand.	HD6	18,000	34x7	Con 18R	Six (4x4½)	2,544	6.16	32.9	0.042	0.198	
General Motors	T44-4403	14,000	36x6	Buick	Six (3$\frac{7}{16}$x4⅝)	2,220	8.05	40.9	0.058	0.260	
Gramm-Bernstein	A	18,500	36x8	Con 18R	Six (4x4½)	2,544	7.25	68.8	0.045	0.379	
Hug	86	16,960	36x6	Bud DW6	Six (3¾x5)	2,400	7.85	46.8	0.050	0.265	
Indiana	127	17,000	S36x10	Her	Four (4½x5¾)	2,736	8.00	42.8	0.061	0.288	
Indiana	190	19,000	34x7	Con	Six (4⅛x4¾)	2,832	7.75	78.6	0.055	0.497	
Internat'l Harves.	A-5	17,600	34x7	Own FBB	Six (3⅝x4½)	2,160	8.50	76.8	0.050	0.400	
Internat'l Harves.	A-6	17,750	34x7	Own FBB	Six (3⅝x4½)	2,160	7.16	64.7	0.042	0.334	
Kenworth	184	18,500	9.00-20	Her WXC2	Six (4⅛x4½)	2,856	6.80	36.4	0.049	0.231	
Kenworth	185	18,500	36x8	Her YXC	Six (4⅜x4¾)	3,360	7.75	93.5	0.064	0.678	
La-France-Republic	L-1	18,000	36x8	Lyc TS	Six (3⅞x5)	2,976	7.50	48.7	0.056	0.323	
Average									0.0535		0.0607
					5-Ton Trucks						
Acme	90L	21,500	S40x12	Con B7	Four (5x6)	3,456	8.75	83.1	0.060	0.502	
Autocar	C	26,000	42x9	Own	Six (4½x4¾)	3,708	8.46	61.7	0.047	0.302	
Autocar	TFA	26,000	38x9	Own	Six (4½x4¾)	3,708	7.10	101.0[k]	0.043	0.478	
Brockway	T	28,000	S40x14	Con	Four (5x6)	3,456	10.00	95.0	0.053	0.438	
Brockway	250	25,000	40x8	Con	Six (4⅜x4¾)	3,216	10.00	73.0	0.053	0.338	
Coleman[j]	X-100	24,300	42x9	Bud BA6	Six (4⅛x5⅛)	3,000	8.54	140.0	0.039	0.563	
Coleman[j]	X-100F	29,800	42x9	Bud GL	Six (4½x6)	4,296	8.54	175.0	0.045	0.823	
Day-Elder	240	24,000	38x9	Con 21R	Six (4⅜x4¾)	3,216	9.66	51.7	0.055	0.260	
Diamond T	1000	28,000	S40x12	Her YXC2	Six (4½x4¾)	3,576	11.66	62.4	0.064	0.300	
Douglas	F4	26,000	S40x12	Bud BBU	Four (5x6½)	3,624	9.12	57.5	0.054	0.302	
Douglas	F6	26,000	9.75-20	Bud GL	Six (4½x6)	4,296	10.30	64.4	0.077	0.422	
Fisher-Stand.	100C	25,000	36x8	Con 21R	Six (4⅜x4¾)	3,216	8.75	83.2	0.051	0.428	
F.W.D.[j]	M5	23,000	12.75-20	Wau SRL	Six (4⅜x5⅛)	3,624	10.00	207.0	0.059	1.070	
General Motors[j]	T90-9001	23,000	7.50-20	Buick	Six (3¾x5)	2,760	9.25	76.0	0.053	0.384	
Gramm-Bernstein	HV	22,500	36x8	Con 21R	Six (4⅜x4¾)	3,216	9.00	85.5	0.058	0.488	
Indiana	250	25,000	40x8	Con	Six (4⅜x4¾)	3,216	10.00	73.0	0.053	0.339	
Internat'l Harves.	HS-104C	29,895	S40x14	HAS 152	Four (4¾x5½)	2,640	10.10	90.5	0.038	0.300	
Lange	T	26,000	40x8	Her YXC2	Six (4½x4¾)	3,576	10.00	96.0	0.056	0.476	
Maccar	86	22,900	S36x6	Bud BA6	Six (4⅛x5⅛)	3,000	9.66	51.7	0.061	0.286	
Maccar	86A	25,000	10.50-22	Her YXC3	Six (4⅝x4¾)	3,816	7.80	74.1	0.052	0.452	
Walter[j]	FHS	26,000	9.75-24	Own 6	Six (4½x5¾)	3,984	8.50	85.0	0.050	0.444	
White	64	23,000	36x8	Own 1AB	Six (4⅜x5¾)	3,924	7.16	46.8	0.055	0.320	
Average									0.0535		0.0605

Note:—Data obtained from *Commercial Car Journal's* specification tables and engine manufacturers' torque figures. "S" before tire size indicates use of solid tires. The accuracy of the *TF* figures is within the possibilities of a 10-in. slide rule.

[i] This is 0.755 if through four gears; whereas, eight are used.

[j] Extra transmitting parts over conventional assumed to be 95 per cent efficient.

[k] Auxiliary transmission assumed as 88¼ per cent efficient.

pavements we have in our cities and keep tire costs down, if you run over 9 m.p.h.

The slow-moving truck on which these opinions were based has been replaced by an entirely different vehicle, shod with pneumatic instead of solid tires and having

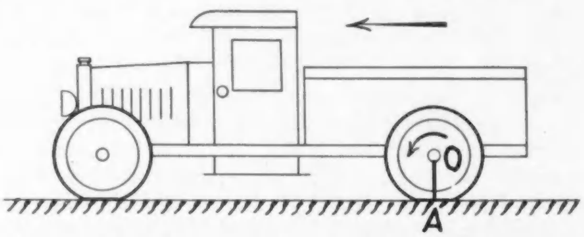


FIG. 1—THE ROLLING RADIUS *OA* IS OF PRINCIPAL CONCERN. IT CAN BE OBTAINED BY MEASUREMENT OF ITS STANDING HEIGHT OR BY CONSULTING THE FIGURES GIVEN IN TABLES 1 AND 2

a mobility and maneuverability undreamed of at that time by the pioneers.

Typical Modern-Truck Tractive-Factors

The tractive factors of a typical line of modern trucks are listed in Table 3 in the two left-hand columns. At the right are corresponding figures taken from C. T. Myers' paper[3].

A certain latitude must be allowed in Table 3 for the comparison with the 1912 models of equal tonnage because of the arbitrary ratings by tonnage of that day and now. We are more liberal in our weight allowances today. Truck design has reached a point of stability, as indicated by the closer range of tractive-factor figures in high gear for the various classifications. Were comparisons to be made in the "low" gears, modern figures would be startling. Whereas 30 to 1 formerly was considered a suitable over-all reduction, we are employing today 70 to 1 and 80 to 1, with an extreme of 180 to 1 and 207 to 1 in some four-wheel-drive designs. Today's transmissions, with four speeds in the smaller trucks and five and seven in the larger, have made this possible. Over-all reduction-ratios have been steadily increasing and, based on today's practice, this is the most important element in the tractive-factor formula for low-gear work.

Same Payload and Decreased Weight

In his paper on Use of Aluminum Alloys in Commercial Motor-Vehicles, beginning on p. 637 of this issue, Mr. Goll shows forcefully the economics in the use of this material for bodies by carrying extra payloads equal to the weight saved by its use. For the purpose of considering performance ability, let us keep the payload the same and see what results are obtained through decreased weight. In his first example, a gross weight of 22,000 lb. is had with a steel body; it would become 20,200 lb. through the use of aluminum, due to the saving of 1800 lb. in body weight. With the steel body,

$$TF = \frac{2160 \times 10.8 \times 0.85}{18.7 \times 20{,}000} = 0.048;$$

but with the aluminum body

$$TF = \frac{2160 \times 10.8 \times 0.85}{18.7 \times 20{,}200} = 0.052.$$

The engine develops a maximum torque of 2160 in. lb., a 10.8 to 1 reduction is used and the pneumatic tires are 36 x 6 in. Actually, the increase would be greater than that indicated, because I have taken Mr. Goll's weight of the 6½-cu. yd. aluminum-body which replaced the 5-cu. yd. steel body. A 5-cu. yd. aluminum-body should result in a further decrease of 200 lb., in which case $TF = 0.053$. The weight saving of the 5-cu. yd. aluminum body is equivalent to a 10.4-per cent increase in torque output of the engine to get equal performance when using the steel body.

Author Develops an Economic Factor

An abnormally large engine would aid in giving a vehicle a large tractive-factor figure, at the expense of economy. The latter, expressed in miles per gallon or, better, in ton-miles per gallon, is an important item in maintenance costs. It is therefore suggested that, before making a hurried decision on the basis of the tractive factor alone, consideration be given also to the economical side of the situation. For this purpose I have developed an economic factor, based on the number of cubic inches of piston displacement required to move 1 lb. of weight based on the gross weight a distance of 1 mile. This presupposes that 1 cu. in. of displacement will develop the same amount of power in one engine that it will in another. Compression ratio, combustion-chamber shape, valve size and timing, manifolding, carbureter setting and the like are some of the variables that would determine the ability of one engine to utilize a cubic inch of mixture better than would another engine. However, for the sake of comparison, such a method would serve to indicate the possibility of sacrificing economy unduly for performance. One-half the displacement is utilized in the formula, since it is more in keeping with the "inspirating" of a four-

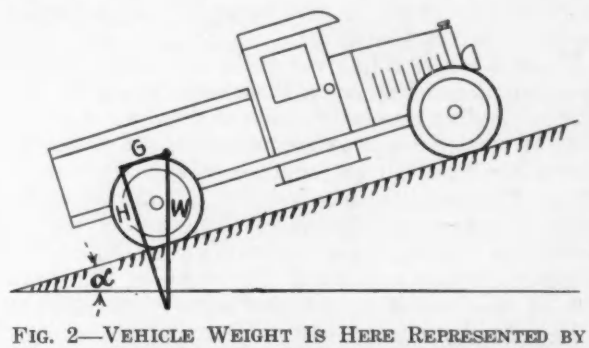


FIG. 2—VEHICLE WEIGHT IS HERE REPRESENTED BY *W*, AND THIS CAN BE RESOLVED INTO THE COMPONENTS *G* AND *H*. THE LATTER IS PERPENDICULAR TO THE ROAD SURFACE AND COMPONENT *G* IS PARALLEL THERETO. AN EXTRA FORCE EQUAL AND OPPOSITE TO *G* MUST BE EXERTED BY THE VEHICLE TO OVERCOME THE ADDED GRADE-RESISTANCE

cycle engine. The number of cubic inches per mile in high gear is then:

$$\frac{5280 \times 12}{2\pi r} \times R \times \frac{D}{2} = \frac{5042 \times R \times D}{r} \qquad (6)$$

and the number of cubic inches per pound per mile is:

$$EF = \frac{5042 \times R \times D}{r \times W} \qquad (7)$$

where

EF = economic factor
R = axle ratio
D = displacement
r = rolling radius of tire
W = gross weight in pounds

[3] See S.A.E. TRANSACTIONS, 1913, vol. 8, part 1, p. 107.

As an example, let us compare two 3-ton trucks each having a gross weight of 19,000 lb. Let truck *A* have a six-cylinder, 4¼ x 4¾-in. engine, which gives a displacement of 404 cu. in. The axle ratio is 6.9 to 1 and the tires are of 34 x 7-in. size. Let truck *B* have a 4⅛ x 4¾-in. six-cylinder engine, a displacement of 381 cu. in., and an axle ratio of 7.75 to 1. The tires are of the same size, 34 x 7 in. According to formula (7), the EF for truck $A = 42$ cu. in., and the EF for truck $B = 40.5$ cu. in. Everything being equal, truck *B* would be more economical than truck *A*. If one engine should give a greater output than another through the better utilization of the fuel charge inspirated, it should be made evident by the greater output. Such an advantage is taken note of in formula (4), in which the torque is a factor.

Tractive Resistance versus Effort

Thus far we have only considered the vehicle and its ability. As was once said "the other half of the automobile is the road it runs on," for the one is useless without the other. The resistances that a vehicle encounters in transit must be considered, as these opposing forces control its manner of progress to a large extent. If they are greater than the tractive effort that the vehicle can exert, then the excess will retard it. This is the basic reason for the different ratios provided by the gearbox. If the vehicle cannot make progress in high gear, we drop back to a lower gear and, in so doing, the tractive effort is increased because of the greater value of the over-all reduction in formula (5). If the tractive effort is greater than the external resistances, the excess TE will accelerate the vehicle. The external resistances consist of (*a*) rolling resistance, (*b*) grade resistance and (*c*) air resistance. Their sum is called the tractive resistance and is naturally opposed to the tractive effort.

When a wheel rolls over a surface distortion occurs, its extent depending upon the character of the surface. If it is yielding or plastic, such as mud, a rut is formed. If it is elastic, such as asphalt, a slight deflection occurs under load but the surface resumes its former position after the load has passed. All this is at the expense of energy consumption. The former case represents high road-surface resistance; the latter, low resistance. While outside of the scope of this paper, it will be seen readily that the tests of the Bureau of Public Roads, United States Department of Agriculture, covering load distribution on road surfaces, tie in with the general interests of this discussion. At the same time that a wheel rolls, distortion occurs known as tire-displacement resistance, representing a power loss. There are also wheel-bearing friction and wheel windage, although these items are very small in amount.

Tire-displacement resistance is due to the constant flexing of the casing. As the wheel revolves, each part of the tire is deformed and there is a continuous wave of displacement of material. The extent will depend on the type and size of tire, contact area or unit pressure, the tire pressure in the case of pneumatics, the number of plies and the mechanical construction, the resiliency of the tire, temperature and speed.

Rolling-resistance data from tests conducted at the engineering experiment-station at the North Carolina State College will be found in Tables 6 to 10 shown in the Appendix and convey valuable information to those who are particularly interested in this subject.

The tire manufacturers no doubt have a wealth of information on this subject and I hope that they will divulge some of it, particularly on commercial low-pressure tires. Very little information is available except on the passenger-car type. In passing, it is interesting to note that our former President, Henry Souther, did considerable research work on tire deformation and resistances in the bicycle days, such as coasting down inclines to evaluate the various problems presented.

Energy is also consumed by impacts between the wheel and the road due to unevenness in the road. Abnormal distortions occur in both. It has been found practically impossible to evaluate these conditions due to their irregularity and variety. There is no doubt that the spring-suspension plays an important part in the combination. However, for our purpose of making vehicle comparisons, we can safely assume uniform road-conditions.

TABLE 4—RESISTANCE TO ROLLING OF PNEUMATIC-TIRED VEHICLES OVER VARIOUS ROAD-SURFACES

Road Surface	Condition	Rolling Resistance Lb. per Ton of Load	Rolling Resistance Per Lb. of Load
Concrete	Browne and Lockwood Tests	18 to 38	0.009 to 0.019
Asphalt	Good[1]	14	0.007
	Hard, Smooth	22	0.011
	Poor	26	0.013
	Pavement	46 to 62	0.021 to 0.031
Wood	Paving	26	0.013
Macadam	Smooth and Dry	30	0.015
	Good	34	0.017
	Best	38 to 42	0.019 to 0.021
	Slightly Defective, Reasonably Dry	36	0.018
	Good, Softened by Rain	40	0.020
	Dry and Dusty	42 to 48	0.021 to 0.024
	Slightly Defective, Softened by Rain	44	0.022
	Ordinary	44 to 54	0.022 to 0.027
	Hard Best, Wet	48 to 64	0.024 to 0.032
	Bad State of Repair	50	0.025
	Good, Softened	70	0.035
	Soft	86	0.043
	Bad	44 to 90	0.022 to 0.045
Dirt	Dry and Good	30	0.015
Belgian Block	Irregular	44	0.022
Granite Block	Good	54	0.027
Flint	Rolled	74	0.037
	Soft	92	0.046
Cobbles	Ordinary	116	0.058
	Bad	Up to 220	0.110
	Very Bad	220	0.110
Clay	Hard Dry	90	0.045
	Best	98	0.049

[1] See diagrams for automobile power-calculations, by George Watson; *American Machinist*, Dec. 20, 1906, p. 806.

If a vehicle be towed and the draw-bar pull recorded, the draft in pounds per ton is easily reckoned. To prevent the chassis losses from being included, the axle shafts are withdrawn in the case of a full-floating axle, or the final-drive gearing is partially removed—pinion or worm—with other axles. In order that the vehicle propel itself under the same road conditions, it must exert sufficient tractive effort to balance this resistance. Numerous investigators have compiled figures on the rolling resistance of rubber-tired vehicles, both solid and pneumatic, over various surfaces. In general, it has been found that the minimum rolling-resistance is about 22 lb. per ton of weight on the tires. Some figures of interest indicating the increased resistance of various road surfaces will be found in Table 4, reproduced from W. S. James' paper on Elements of Automobile Fuel Economy[4].

For the purpose of comparison we will assume 22 lb. per ton. This corresponds to hard smooth asphalt in Table 4, and we will take this as our standard road. In

[4] See S.A.E. TRANSACTIONS, 1921, vol. 16, part 2, p. 196.

the same manner that we converted the tractive effort to the tractive factor in dividing by the gross weight, we will also convert the tractive resistance to the resistance factor, *RF*, by dividing by the weight on the tire, which in this case is 2000 lb. In other words the rolling resistance per pound of weight $= 22/2000 = 0.011$. The value of *TF* must never be less than that for *RF* or the vehicle cannot proceed. The excess of *TF* over *RF* determines the performance ability of the vehicle.

If a vehicle be ascending a grade, greater effort is called for because of the work against gravity. In Fig. 2, let *W* represent the weight of the vehicle. This can be resolved into the components *G* and *H*. Component *H* is perpendicular to the road surface, and *G* is parallel thereto. An extra force equal and opposite to *G* must be exerted by the vehicle to overcome the added grade-resistance. Should a vehicle be going down a grade, this value would be substracted from the tractive effort. The horizontal effort to move a vehicle up a grade of a given percentage is equal to the same percentage of its weight, following the law of the inclined plane. Thus a 5-per cent grade would require an effort equal to 5 per cent of the vehicle weight; or, for each pound, the effort required would be 0.05 lb. This resistance factor can now be added to the rolling resistance to consider the total resistance offered a vehicle ascending a hill, not considering air resistance.

The rolling resistance factor we found to be 0.011. If this stretch of road extends up a 5-per cent grade, the total resistance factor would be $0.011 + 0.050 = 0.061$. In the example previously given of the 18,000-lb. motorcoach with a 4.8 to 1 axle ratio, the tractive effort was 0.061. We know now that the grade can just be negotiated in high gear. If the transmission has a 5 to 1 low gear, what maximum grade would the motorcoach climb? The tractive factor would be 0.270 according to formula (5). Subtracting the rolling resistance, 0.011, we have left 0.261. In other words a 26-per cent grade, of hard-surfaced road, could be negotiated in low gear.

Tractive Resistance Considered

Air resistance was practically discounted in connection with commercial vehicles in former days due to their slow speeds. However, today's pace makes it an important factor and particularly so with motorcoaches. The size and shape of the vehicle determine this resistance. "Streamlining" is becoming more and more evident, and there is no doubt that the formula which, until now, has only considered the cross-sectional area of the vehicle, will have to be modified as streamlining design evolves. It is generally conceded that air resistance increases as the square of the speed and directly with the projected area. Motorcoaches present a large area, and the air resistance can build up to a considerable extent if strong head-winds are encountered. The general air resistance formula used is

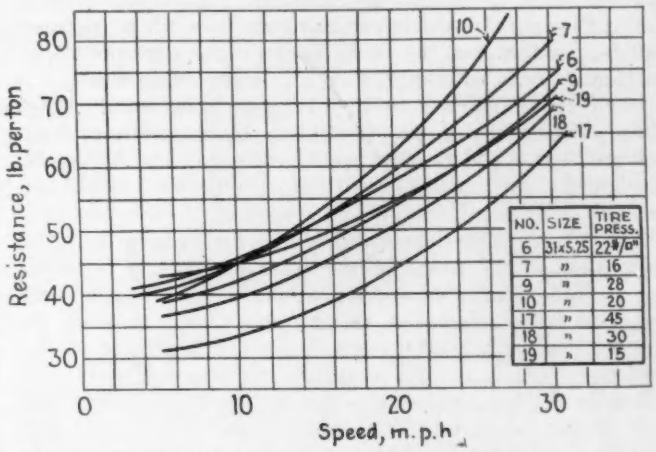


FIG. 3—VARIATION OF TRACTIVE RESISTANCE WITH A VARIATION IN TIRE PRESSURE WHEN LOAD REMAINS CONSTANT. THE RUNS WERE MADE ON GOOD CONCRETE PAVEMENTS

$$R_a = CAV^2 \qquad (6)$$

where

R_a = total air resistance, in pounds
A = projected cross-section of the vehicle, in square feet
V = speed of the vehicle relative to the air, in miles per hour
C = an experimental coefficient, which can be taken as 0.0025

The rolling resistance and grade resistance are independent of the speed of the vehicle. Air resistance is

TABLE 5—AVERAGE ROLLING-RESISTANCE

Type and Condition of Roadway Surface	Average Values, Rolling Plus Air Resistance: Solid Tires, 10 M.P.H.	Pneumatic Tires, 15 M.P.H.	Pneumatic Tires, 25 M.P.H.	Pneumatic Tires, 35 M.P.H.
Portland-cement concrete: best, newly finished	30	22	27	35
Portland-cement concrete: rough due to poor work	36	30	35	42
Portland-cement concrete: average good condition	32	27	32	39
Asphaltic concrete coarse graded type, at average yearly temperature: best	30	25	30	37
Asphaltic concrete coarse graded type, at average yearly temperature: average	33	27	32	39
Sheet asphalt at average yearly temperature: best	28	23	28	35
Sheet asphalt at average yearly temperature: average	36	30	35	42
Bituminous filled brick, average, no filler on surface	30	26	31	38
Grout-filled brick, average	37	30	38	45
Wood block bare of filler, average uniform surface	35	30	34	40
Gravel: best, clay bound	40	35	40	47
Gravel: fair to poor, rough spots, some loose material	55	50	55	62
Gravel: poorest condition, rough and many loose pieces	60	55	60	65
Gravel: Iowa yearly average, approximated	50	45	50	57
Natural soil, good, well graded and patrol maintained	45	35	40	47
Natural soil: soft, or slightly spongy	70	70	75	80
Natural soil: Iowa yearly average, approximated	55	45	50	58
Snow: 2 in. thick and well packed	55	50	70	..
Snow: about 4 in. thick, slightly packed	75	70	..	..
Snow: about 4 in. thick, slightly packed, with chains on wheels	75	..	..	..
Average for: best paved surfaces, concrete, asphalt, brick and wood block	30	22	27	37
Average for: partly worn pavements; that is, in fair average condition	35	30	35	42
Yearly average for: best gravel of type used on trunk lines	45	40	45	55
Yearly average for: ordinary gravel found on secondary roads	55	50	55	65
Yearly average for: well-maintained county system earth roads	65	60	63	75
Yearly average for: well-maintained primary system earth roads	55	50	53	65

the one that is dependent thereon. It is felt that in making general vehicle-comparisons the air resistance can be omitted, on the basis that practically like cross-sectional areas of vehicles of the same class exist. It is well to remember to avoid large areas where possible. Streamlining has been ably discussed in the paper entitled Wind Resistance of Automobiles[5], by F. W. Pawlowski, and considerable effort will be further expended in general design and research.

Prof. T. R. Agg has conducted many tests on tractive resistance at the Iowa State College, and it is interesting to note that the rolling and air resistances were recorded collectively. A vehicle was towed in each direction over the test course and draft records were kept throughout the speed range. Subsequent tests consisted in towing the vehicle at the desired speed to one end of the section of the road constituting the test course, and then releasing it from the towing vehicle and allowing it to coast. A space-time recorder was used as a means for measuring deceleration. Tire, pavement and air temperatures and wind direction and velocity were recorded. The importance of maintaining proper pressure can be appreciated by noting the results[6] shown in Fig. 3.

[5] See S.A.E. JOURNAL, July, 1930, p. 5.
[6] See Iowa State College Bulletin No. 88, p. 44.
[7] See Iowa State College Bulletin No. 67, p. 24.
[8] See Iowa State College Bulletin No. 67, pp. 13 and 23.

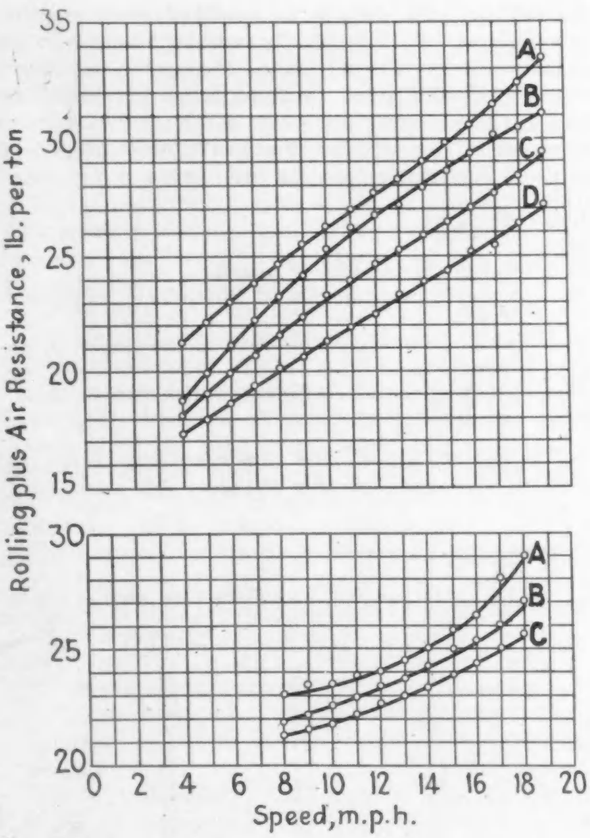


FIG. 4—EFFECT OF TIRE TEMPERATURE ON ROLLING RESISTANCE

The Curves Are for an F.W.D. Truck Having a Gross Weight of 9120 Lb. and Running on a Portland-Cement-Concrete Pavement. For the Upper Diagram, 36 x 4-In. Solid Tires Were Used and the Tire Temperatures for Curves *A*, *B*, *C*, and *D* Were, Respectively, 85, 88, 94 and 102 Deg. Fahr. Pneumatic Tires 40 x 8 In. in Size Were Used for Curves *A*, *B* and *C*, in the Lower Diagram, the Respective Tire Temperatures Being 103, 108 and 110.5 Deg. Fahr.

Tire temperatures may seem unimportant in their relation to total rolling resistance. We have been aware of the effect of brake-drum heat on pneumatic tires but we also find that the tire temperature makes a difference in tractive resistance[7], as indicated in Fig. 4. Other than the temperature effect on the enclosed volume of air, some investigators have found that the tire carcass expands inwardly under the influence of heat, resulting in a reduction in volume. When a vehicle is put into operation, the tire temperature rises slowly and finally reaches equilibrium temperature; at this point the heat is dissipated to the air as rapidly as it is generated. The maximum temperature reached will vary with the air temperature as well as with the usage. This results in a reasonable variation in rolling resistance which, in the case of solid tires, may reach a considable portion of the total rolling resistance but is less marked in the case of pneumatic tires. This general relation is shown in Fig. 4.

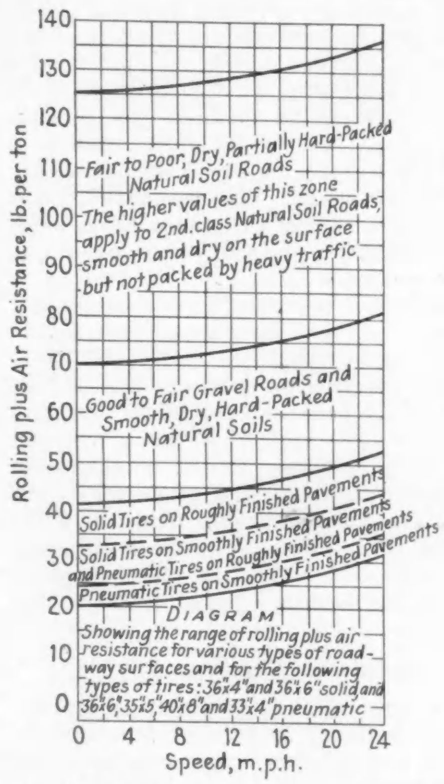


FIG. 5—RANGES OF VALUES OF ROLLING PLUS AIR RESISTANCE FOR ALL TYPES OF ROADWAY SURFACE INCLUDED IN THE INVESTIGATION

Professor Agg found the rolling plus air resistances, in pounds per ton, by means of the coasting method already mentioned, for various road surfaces. These are given in Table 5, and Fig. 5 indicates the range of values[8].

In conclusion, I wish to emphasize that the subject of this paper could well be expanded into a book. Many of the phases involved could not even be touched upon herein. For all practical purposes, the understanding and interpretation of formulas (4) and (5) will enable the operator to compare different vehicles, the higher value indicating the better-performing vehicle. At one time the tractive factor was discussed considerably, but gradually it dropped by the wayside. It is a most convenient element in traction-resistance determinations. I am hoping that the 1930 Transportation Meeting will have brought it again into the foreground. For those particularly interested in the subject, the references given are worthy of further perusal; in them, the reader will find many other valuable references.

APPENDIX

The results recorded in Tables 6 to 11 were made by a testing machine consisting of a wheel and tire mounted so that the tread rested on top of the face of a large wooden drum 17.6 ft. in circumference, for which 300 revolutions equals 1 mile. The wheel was mounted on an axle spindle, the other axle end being held by a vertical pivot. This allowed the wheel end to swing horizontally. Weight was applied to the axle through vertical rods fastened to the ends of a truck spring representing the spring condition of the motor-vehicle.

When the drum is rotated it exerts the tangential force of the tread on the tire and, as the end of the axle carrying the wheel is free to move horizontally, the force necessary to resist movement of the wheel is equal to the tangential force exerted by the drum face. The conditions of a tire rolling on a hard, smooth surface are reproduced and the rolling resistance is measured correctly. There is a small effect due to the drum face having a little curvature, but this effect is slight.

TABLE 6—EFFECT OF OPERATION UPON ROLLING RESISTANCE; 35 X 5-IN. HOOD CORD TRUCK TIRE NO. HW 772,088

The Constants during the Run Were: Speed, 30 M.P.H.; Weight on Tire Tread, 1777 Lb.; and Room Temperature, 75 Deg. Fahr.

Time after Start, Min.	Rolling Resistance, Lb.	Inflation Pressure, Lb. per Sq. In.	Temperature of Tire Tread, Deg. Fahr.
0	22.75	70	74
5	20.75	..	..
10	19.90	..	..
15	19.15	..	..
20	18.75	..	..
25	18.45	..	..
30	18.20	..	..
35	18.00	..	..
40	17.95	..	..
45	17.85	..	..
50	17.75	..	..
55	17.65	..	..
60	17.65	80	106

TABLE 7—EFFECT OF TEMPERATURE UPON ROLLING RESISTANCE; 35 X 5-IN. HOOD CORD TRUCK TIRE NO. HW 772,088

Constants during the Run Were: Speed, 30 M.P.H.; Weight on Tire Tread, 1777 Lb.; Inflation Pressure, 70 Lb. per Sq. In.; and Room Temperature, 71 Deg. Fahr.

Temperature of Tire Tread, Deg. Fahr.	Rolling Resistance of Tire, Lb.
74	22.75
84	22.25
89	21.50
93	21.00
96	20.75
98	20.75
99	20.60
100	20.50

TABLE 8—EFFECT OF WEIGHT UPON ROLLING RESISTANCE; 35 X 5-IN. HOOD CORD TRUCK TIRE NO. HW 772,088

Constants during the Run Were: Speed, 30 M.P.H.; Inflation Pressure, 70 Lb. per Sq. In.; and Room Temperature, 75 Deg. Fahr.

Weight on Tire Tread, Lb.	Rolling Resistance, Lb.	Temperature of Tire Tread, Deg. Fahr.	Calculated Rolling Resistance, Lb. per Ton
1,777	19.25	106	21.66
1,631	17.05	...	20.91
1,484	14.65	...	19.74
1,337	12.60	...	18.85
1,190	11.05	...	18.57
1,043	9.35	...	17.93
898	7.65	...	17.04
750	6.15	...	16.40
601	4.75	...	15.81
454	3.35	...	14.76
304	2.20	95	14.47

TABLE 9—EFFECT OF SPEED UPON ROLLING RESISTANCE; 35 X 5-IN. HOOD CORD TRUCK TIRE NO. HW 772,088

Constants during the Run Were: Weight on Tire Tread, 1000 Lb.; Inflation Pressure, 76 Lb. per Sq. In.; Temperature of Tire Tread, 94 Deg. Fahr.; and Room Temperature, 74 Deg. Fahr.

Speed, M.P.H.	Rolling Resistance, Lb.
15	9.10
20	9.50
25	9.80
30	10.20

TABLE 10—EFFECT OF INFLATION PRESSURE UPON ROLLING RESISTANCE; 35 X 5-IN. HOOD CORD TRUCK TIRE NO. HW 772,088

Constants during the Run Were: Speed, 30 M.P.H.; and Weight on Tire Tread, 1777 Lb.

Inflation Pressure, Lb. per Sq. In.	Rolling Resistance of Tire per 1000 Lb. of Weight on Tire, Lb.	Temperature of Tire Tread, Deg. Fahr.	For Comparison, Rolling Resistance per 1000-Lb. Weight on Tire Tread for 5-In. Cord Tire; by United States Bureau of Standards	
			Maximum Values	Minimum Values
80	10.25	110	13.50	8.20
75	10.50	...	13.75	8.55
70	10.90	...	14.10	8.90
65	11.25	...	14.45	9.35
60	11.65	...	14.90	9.85
55	12.15	...	15.50	10.50
50	12.85	...	16.10	11.15
45	13.65	...	....	....
40	14.60	...	....	....
35	15.70	122	....	....

TABLE 11—HORSEPOWER-TORQUE CONVERSION-TABLE[m]

Hp.	Torque in In-Lb. at R.P.M. 600	700	800	900	1,000	1,100	1,200
24	2,521	2,161	1,890	1,681	1,513	1,375	1,260
26	2,731	2,341	2,048	1,820	1,638	1,490	1,366
28	2,941	2,521	2,206	1,961	1,765	1,604	1,470
30	3,151	2,701	2,363	2,101	1,891	1,719	1,596
32	3,361	2,881	2,521	2,241	2,017	1,833	1,680
34	3,571	3,061	2,678	2,381	2,143	1,948	1,786
36	3,781	3,241	2,836	2,521	2,269	2,062	1,890
38	3,991	3,421	2,993	2,661	2,395	2,177	1,996
40	4,202	3,601	3,151	2,801	2,521	2,291	2,100
42	4,411	3,781	3,309	2,941	2,647	2,406	2,206
44	4,622	3,961	3,466	3,081	2,773	2,521	2,311
46	4,832	4,141	3,624	3,221	2,899	2,635	2,416
48	5,042	4,321	3,781	3,361	3,025	2,750	2,521
50	5,252	4,501	3,939	3,501	3,151	2,864	2,626
52	5,462	4,682	4,097	3,641	3,277	2,979	2,731
54	5,672	4,862	4,264	3,781	3,403	3,094	2,836
56	5,882	5,041	4,411	3,921	3,529	3,209	2,941
58	6,092	5,222	4,569	4,061	3,655	3,323	3,046
60	6,302	5,402	4,727	4,201	3,781	3,437	3,151
62	6,512	5,582	4,884	4,341	3,907	3,552	3,256
64	6,722	5,762	5,042	4,481	4,033	3,667	3,361
66	6,932	5,942	5,199	4,621	4,159	3,781	3,466
68	7,142	6,122	5,357	4,761	4,285	3,896	3,571
70	7,352	6,302	5,514	4,901	4,411	4,010	3,676
72	7,563	6,482	5,672	5,042	4,537	4,125	3,781
74	7,773	6,662	5,829	5,182	4,663	4,239	3,886
76	7,983	6,842	5,987	5,322	4,789	4,354	3,991
78	8,193	7,022	6,144	5,462	4,915	4,469	4,105
80	8,403	7,202	6,302	5,602	5,042	4,583	4,201
82	8,613	7,382	6,460	5,742	5,168	4,698	4,306
84	8,823	7,563	6,617	5,882	5,294	4,812	4,411
86	9,033	7,743	6,775	6,022	5,420	4,927	4,516
88	9,243	7,923	6,932	6,162	5,546	5,042	4,621
90	9,453	8,103	7,090	6,302	5,672	5,156	4,726
92	9,663	8,283	7,247	6,442	5,798	5,271	4,831
94	9,873	8,463	7,405	6,582	5,924	5,385	4,936
96	10,084	8,643	7,563	6,722	6,050	5,500	5,042
98	10,294	8,823	7,720	6,862	6,176	5,614	5,147
100	10,504	9,003	7,878	7,002	6,302	5,729	5,252
105	11,029	9,453	8,272	7,352	6,617	6,016	5,514
110	11,554	9,903	8,665	7,703	6,932	6,302	5,777
115	12,079	10,354	9,059	8,053	7,247	6,588	6,039
120	12,605	10,804	9,453	8,403	7,563	6,875	6,302
125	13,130	11,254	9,847	8,753	7,878	7,161	6,565
130	13,655	11,704	10,241	9,103	8,193	7,448	6,827
135	14,180	12,154	10,635	9,453	8,508	7,734	7,090
140	14,705	12,605	11,029	9,803	8,823	8,021	7,352
145	15,231	13,055	11,423	10,154	9,138	8,307	7,615
150	15,756	13,505	11,817	10,504	9,453	8,594	7,878

[m] By courtesy of the Twin Disc Clutch Co.

Another method, which may be called the "brake-substitutes method," was also used to obtain the rolling resistance of the tire. A brake, with lever arm equal to the radius of the drum, was applied to the drum shaft.

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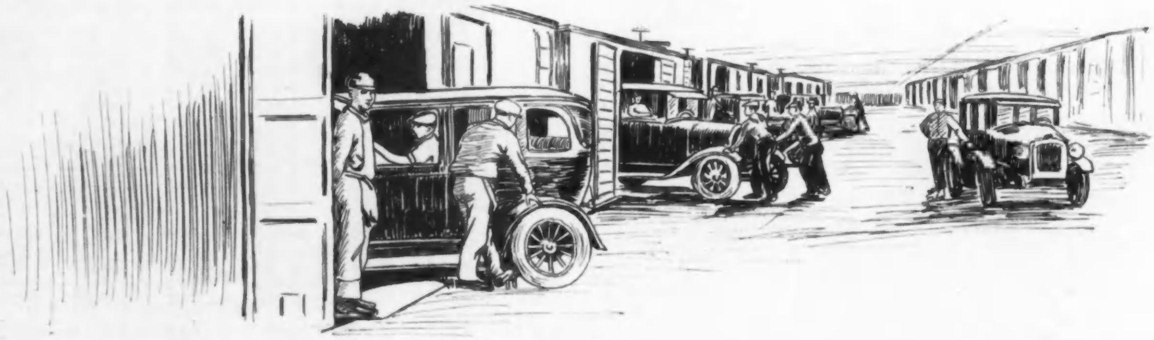


Flight Research
on Maneuverability *and* Spin

By John W. Crowley[1]

18th National Aeronautic Meeting Paper

FLIGHT research conducted by the National Advisory Committee for Aeronautics embraces almost all the problems of flight but the author has confined his paper to descriptions of instruments and test methods used and some of the results obtained in the research that has been conducted on airplane maneuverability and spins.

In the development of special instruments for this work the Committee has standardized upon an optical recording system to eliminate errors due to acceleration effects in the mechanism. The instruments described include a recording accelerometer, a recording turn-meter and a recording air-speed meter. These are used for accurately measuring accelerations and angular velocities of an airplane in any maneuver and also the speed of flight.

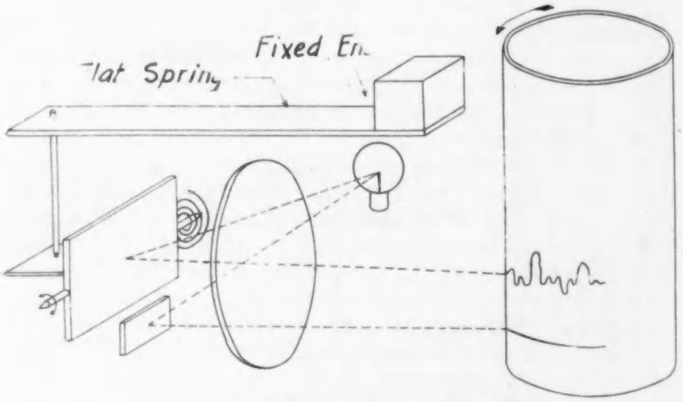
Methods of integrating the records obtained in order to plot the flight path of an airplane in any maneuver, as in a loop, are described. Some of the results obtained are also given. Quantitative data so far obtained on maneuverability are insufficient for the formulation of any generally applicable criterion, but as more are obtained the Committee hopes to be able ultimately to formulate an index of maneuverability and the factors that influence it.

An accurate method for determining the flight path and motion of an airplane during a spin and the forces and movements acting on it has been evolved, which permits the investigation of the effect of changes to the airplane on the spin characteristics. A complete description of the method and computation is to be published soon.

AS THE FLIGHT RESEARCH conducted by the National Advisory Committee for Aeronautics embraces virtually all the problems of flight, to attempt to cover it completely in one paper is out of the question. Therefore I shall confine my remarks to two types of investigation that we term "maneuverability" and "spin," describing the instruments and test methods employed and some of the latest results that are being obtained, mainly to point out the possibilities of flight research, instead of giving at this time any quantity of data of direct use.

[1] M.S.A.E.—Aeronautical engineer, National Advisory Committee for Aeronautics, Langley Field, Hampton, Va.

I think it is obvious that, at the present stage of aeronautic development, little fundamental information is to be gained by observations in flight and that we are obliged to resort to recording instruments for our measurements. The Committee is very fortunate in that from the start of our flight research the importance of special recording instruments has been realized and continued development of instruments has been carried out. Three of these instruments that are used for basic measurements in our maneuverability and spin investigations are the accelerometer, the turn-meter, and the air-speed meter. I shall describe these briefly before discussing the investigations.



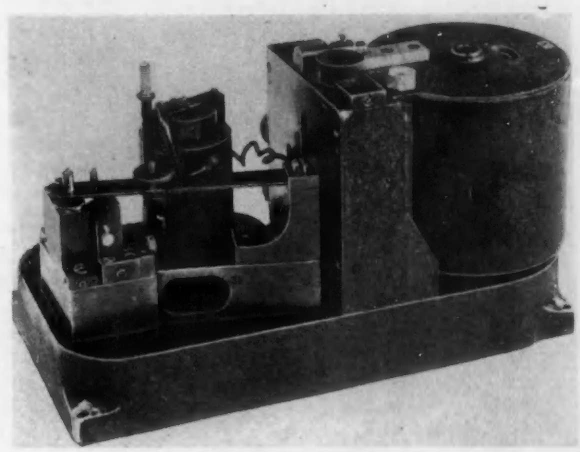
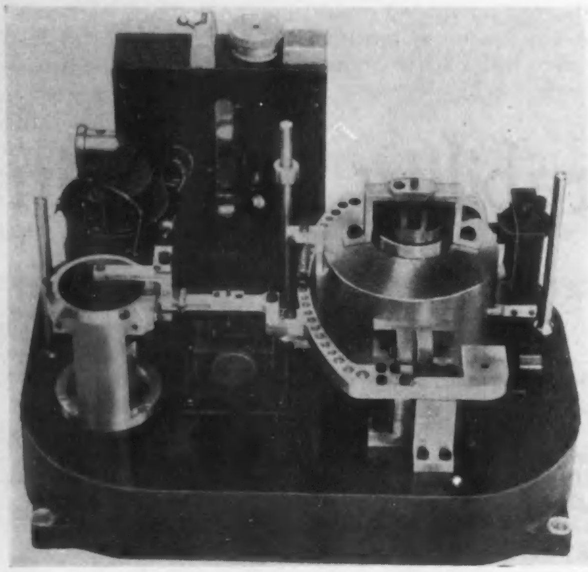


FIG. 1—RECORDING ACCELEROMETER, WITH SCHEMATIC SKETCH OF PHOTOGRAPHIC RECORDING SYSTEM

Acceleration Deflects the Free End of the Cantilever Spring, Which Slightly Rotates the Mirror Below on Its Horizontal Shaft. A Beam from a Light Source Is Reflected by the Mirror through a Lens and Traces a Record on the Film on the Vertical Rotating Drum. A Smaller Fixed Mirror Traces a Reference Line



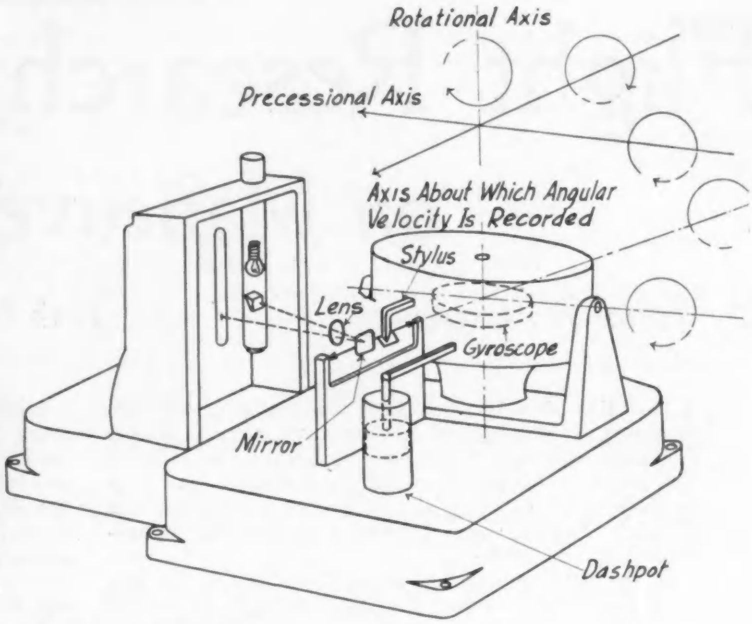
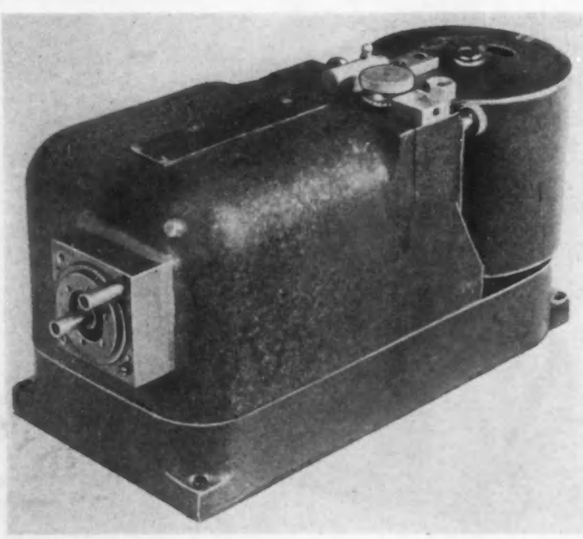


FIG. 2—RECORDING TURN-METER

Angular Velocity Is Determined by Measuring the Precessional Force Exerted by a Gyroscope

Optical Recording System—Recording Accelerometer

Numerous problems arise in connection with the development of flight-recording instruments, not the least of which is the elimination of acceleration effects on the recording mechanisms. The errors due to accelerations have been largely eliminated in N.A.C.A. instruments by the use of an optical recording system that has been standardized upon by the Committee. This system consists essentially of a light source, a lens, a film drum and a rotating mirror. It is shown in Fig. 1, where the optical system is illustrated as adapted to a recording accelerometer. In this instrument the free end of the flat cantilever spring is depressed under the effect of acceleration, the mirror is rotated, and the reflected light-beam, which is reduced to a spot of light by suitable slits before it reaches the film, is moved in a vertical direction across the face of a film drum. The drum is rotated at a constant speed by the motor shown in the photograph on the right. As a consequence of the film rotation and the light travel, a line is traced on the film recording the depression of the spring throughout any maneuver in which the instrument is in operation. The amount of depression of the spring for any acceleration is found by calibration and consequently a history of the acceleration in any maneuver during which the instrument is in operation is determined. The particular instrument illustrated measures accelerations along one axis only. By mounting three such springs mutually perpendicular to one another in one instrument, accelerations along three mutually perpendicular axes can be measured and the resulting acceleration acting on an airplane can be readily determined. The three-component accelerom-



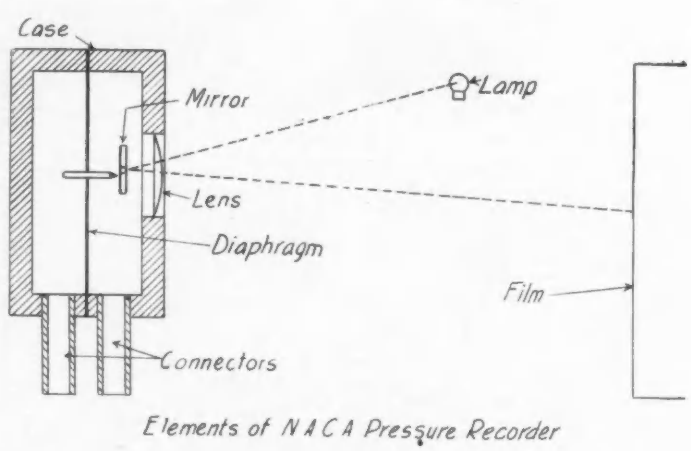


FIG. 3—RECORDING AIR-SPEED METER

A Diaphragm Is Mounted in a Case To Divide It into Two Chambers, One of Which Is Connected to the Impact Side of a Pitot Tube and the Other to the Static Side. Change in the Dynamic Head of the Pitot Tube Deflects the Diaphragm, Which Tilts the Mirror Moving the Light Beam

eter, rather than the single-component accelerometer illustrated, is used in most work involving airplane maneuvers.

Recording Turn-Meter

A second type of instrument that is used in the work I shall describe later is the recording turn-meter. Angular velocity is determined with this instrument by measuring the precessional force exerted by a gyroscope when it is subjected to angular velocities. As illustrated in Fig. 2, a gyroscope rotating about a vertical axis and pivoted about a horizontal axis is employed. The gyroscope is restrained from rotating about the pivot axis by coil springs not shown in the diagram. When an angular velocity about an axis in the horizontal plane perpendicular to the pivot axis is imposed on the gyroscope, it tends to precess about the pivot axis. The precessional force generated causes a deflection of the springs, which allow the gyroscope to turn slightly, and this movement is recorded by an optical system of the same type as was previously described. The precessional force is directly proportional to the angular velocity imposed, so consequently the deflection of the springs, which is measured, is also a measure of the angular velocity imposed. The deflections for different angular velocities are calibrated by means of a turntable constructed for this purpose. For a maneuver in which motion occurs in more than one plane three of these instruments are used, mounted so as to measure the angular velocity about three mutually perpendicular axes, usually the three reference axes of the airplane.

Recording Air-Speed Meter

A third instrument that I want to mention briefly is the recording air-speed meter shown in Fig. 3. This instrument uses the deflection of a metal diaphragm under load as the measuring unit. The diaphragm is enclosed in a case, as shown, and separates the case into two chambers. One chamber is connected to the impact side of a pitot static-head and the other to the static side. As the dynamic head on the pitot tube changes, the diaphragm deflects, and this deflection is optically recorded as shown.

MANEUVERABILITY INVESTIGATIONS

The rating of an airplane with regard to its ability to maneuver is at present based almost entirely upon individual opinions rather than on any definitely established accomplishments. We have started a collection of quantitative data with respect to the maneuverability of different airplanes, from which we hope not only to compare the merits of the airplanes investigated but also ultimately to formulate a satisfactory criterion or index of maneuverability and the factors which influence it. In obtaining these data we have given particular attention to certain maneuvers of immediate interest, particularly pulling out of dives at high speeds. The results have been carried to a more complete stage in respect to the pull-outs than to any other maneuver, and I shall call attention to these results later.

Our basic consideration in the study of maneuvers has been to determine the flight path of the airplane and its motion along that path. We have developed two methods for this, one using photographs made from the ground by a special camera obscura built for this purpose, and the second making use of the instrument records obtained in the airplane. I shall not describe the former. It was developed primarily to provide a check on the instrument flight-path determination, and, while accurate, is involved in that it requires constant communication with the airplane, and is dangerous because it necessitates the execution of maneuvers at rather low altitudes. I shall, however, describe the instrument method which we now standardize upon except for occasional checking by the camera obscura.

Flight-Path Determination by Instrument Method

By means of the instruments described, together with other similar instruments for more incidental information, we are able to obtain a history, similar to that shown in Fig. 4, of any maneuver. These measurements were obtained in a loop and give the variations

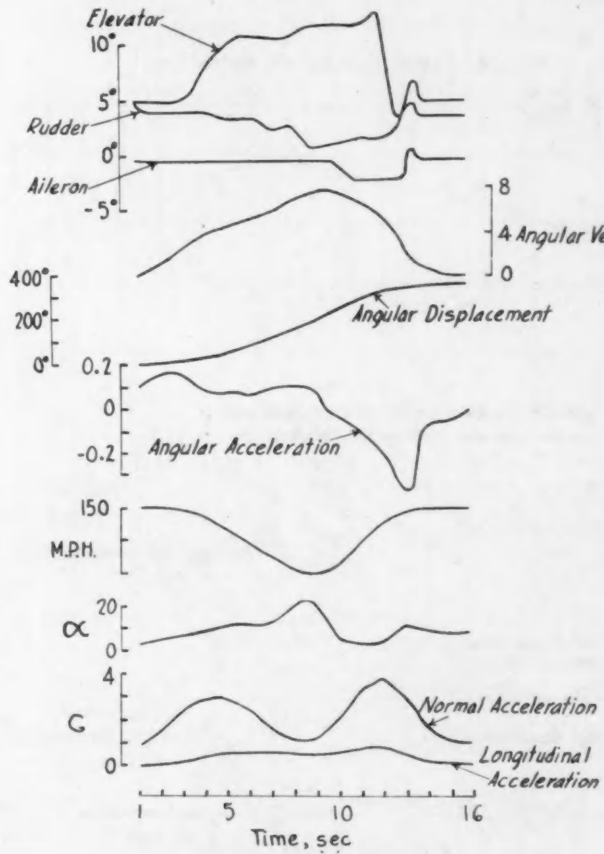


FIG. 4—MEASUREMENTS OBTAINED IN A LOOP

The Curves Give the Variations against Time for Movements of the Elevator, Aileron and Rudder, the Angular Velocity, Displacement and Acceleration, the Air-Speed, the Angle of Attack and the Normal and Longitudinal Acceleration

against time for the elevator, aileron and rudder movements, the angular velocity, angular displacement and angular acceleration, air-speed, angle of attack, normal acceleration and longitudinal acceleration. Since the loop is made in a vertical plane, no lateral acceleration is developed. Making use of such information as is shown on this chart, we have developed the instrument method of flight-path determination illustrated in Fig. 5. Reproduction of actual records of angular velocity and accelerations in a loop are shown to the left of the figure. The lines across these records are placed simultaneously on all records by means of a chronometric instrument that flashes a light in each instrument at 1-sec. intervals. These lines serve to synchronize

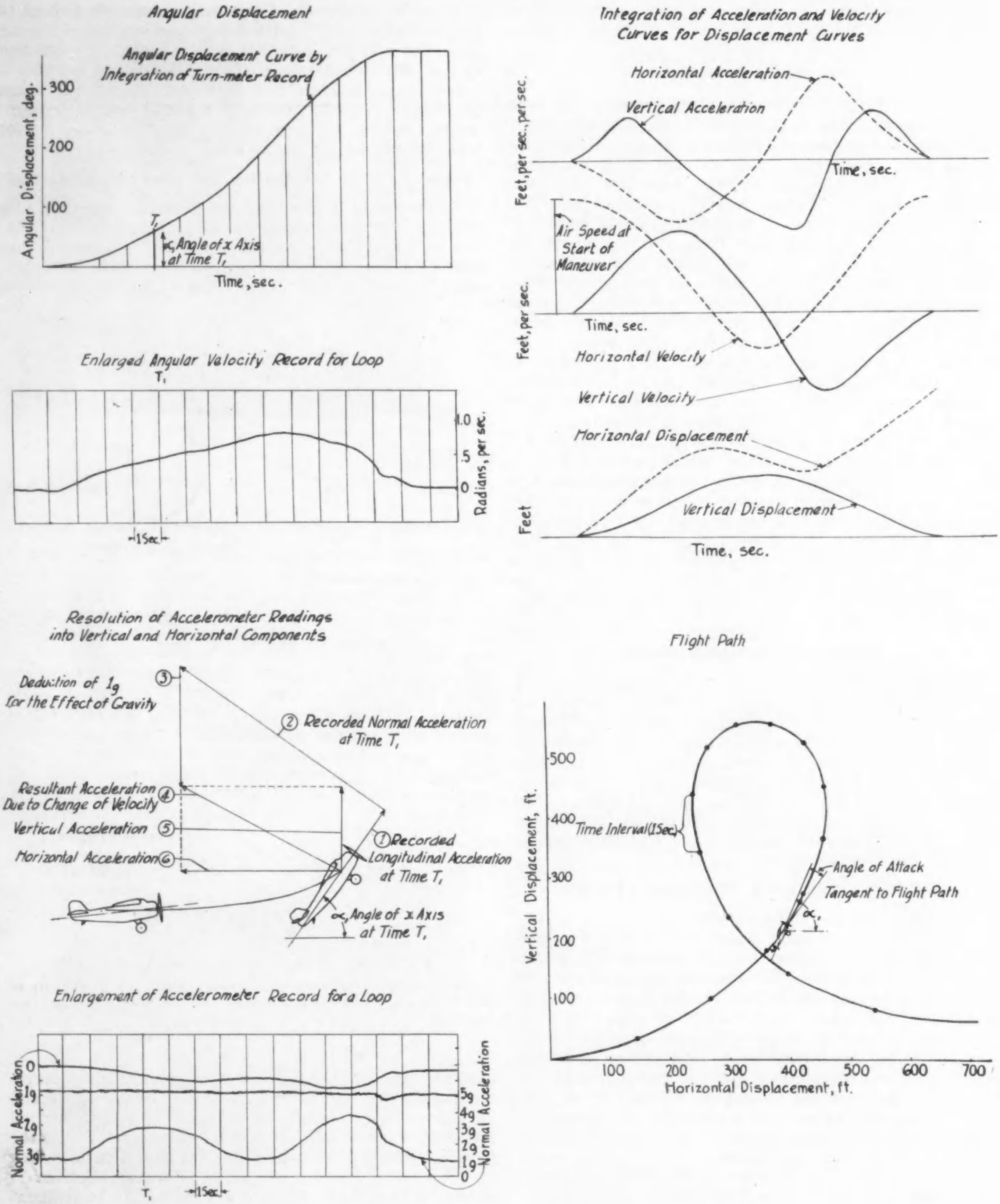


Fig. 5—Method of Determining the Flight Path in a Maneuver

the various records and to establish the time scale. The angular-velocity curve is integrated and the angular-displacement curve just above is obtained. Actually, an integraph is used to draw the integral curve of the angular-velocity curve. The ordinates of this curve give the angular displacement of the airplane from its original position at any time. We find it convenient to start all maneuvers in level flight, so the angular dis-

placements shown here are with reference to the horizontal.

A three-component accelerometer was used, and the accelerometer record therefore shows on the same film the accelerations along the longitudinal, transverse and normal axes of the airplane. At any time, T_1, we have the angular displacement of the airplane and the accelerations acting. These values are plotted vectorially, as shown. The attitude (angular displacement) is first laid off, then the longitudinal and normal accelerations are plotted as vectors. The effect of gravity is allowed for by subtracting 1 g, and the resultant acceleration due to change of velocity is obtained. This is resolved into a horizontal and a vertical component. This procedure is repeated for different times in the maneuver, and the curves of horizontal and vertical acceleration versus time, as shown in the upper right-hand figure, are obtained. Then the integral curves of these accelerations are found, which, together with the velocity of the airplane at the start of the maneuver, as the constant of integration for the horizontal curve, give the horizontal and vertical-velocity curves shown. These latter curves are also integrated, giving the two displacement curves which, when plotted together as shown in the lower right-hand figure, determine the flight path.

This type of work requires extreme accuracy of measurement on the part of the instruments used. We are able, in general, to determine the flight-path coordinate to approximately 5 per cent. The foregoing description applies, of course, to a maneuver executed in one plane. It will be appreciated that for maneuvers executed in more than one plane the computations are much more difficult and laborious.

Altitude Lost in Pull-Out of Dive

Our collection of maneuverability data is as yet too limited to enable us to formulate any generally applicable criterion for maneuverability. However, as previously mentioned, we have carried our analysis of the pull-out of a dive to a more complete stage than for any other maneuver, and one of the results of this work to date may be of interest. The investigation of dives is being made at the request of the Navy Department, one of whose problems in connection with this maneuver is the determination of the loss of altitude necessary for the recovery from a dive at the high speeds used for bombing purposes. It is desirable to release the bomb at as low an altitude as it is possible to recover from without danger of striking the water or overstressing the airplane by a too abrupt pull-out. This requires a knowledge of the loss of altitude necessary for recovery for a normally executed pull-out. The practice has been to compute this very approximately by considering the pull-out to take place along the arc of a circle, without any loss in air-speed, and using the formula $a = \frac{V^2}{R}$, where R is the radius of the flight path or, in a 90-deg. pull-out, is the altitude lost. This assumes a constant value of acceleration throughout the maneuver, whereas experiments have shown that the acceleration is never constant but rises to a peak value shortly after the control is moved and falls off from that value through the rest of the pull-out. The danger in this method of computation is that, where a certain loss of altitude is assumed, the computed acceleration obtained is too low, and where acceleration not to be exceeded is used, the computed loss of altitude will be less than the actual.

From a study of the dive data we have already obtained, we have been able to construct a chart showing relation between altitude lost, acceleration and airspeed, in pulling out of dives in the manner employed in Service conditions. The method of arriving at this chart deviates somewhat from that I described for flight-path determination, but is similar in general principle in that it involves the double integration of linear accelerations as a basis. The chart is shown in Fig. 6,

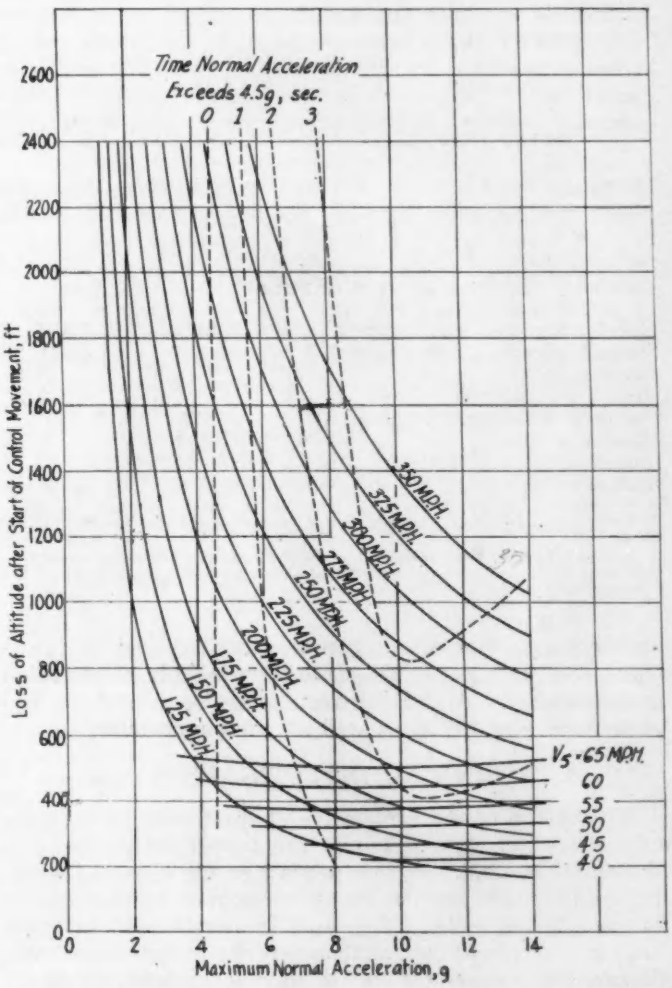


FIG. 6—RELATION BETWEEN LOSS OF ALTITUDE, MAXIMUM ACCELERATION, AND AIR-SPEED IN PULLING OUT OF A DIVE

From This Chart Can Be Determined the Maximum Acceleration Likely To Be Encountered in a Pull-Out at any Speed if a Certain Loss of Altitude Is Desired, or the Loss of Altitude That Will Be Experienced at Any Air-Speed if a Certain Acceleration Is Not To Be Exceeded

and from it can be determined the maximum acceleration likely to be encountered for a pull-out at any speed if a certain loss of altitude is desired, or, conversely, the loss of altitude that will be experienced at any airspeed if a certain acceleration is not to be exceeded.

The interval of time that a reasonably high value of acceleration is experienced is of interest, since experience has shown that a pilot is more affected by a moderately high acceleration acting for a considerable length of time than by a high acceleration acting for a very short time. The dotted lines in Fig. 6 indicate the time in seconds that an acceleration of 4.5 gravity

is exceeded. The maximum theoretical acceleration possible at various air-speeds was established for several stalling speeds and is also shown on the chart. The chart was developed from a limited number of data on one type of airplane, and is as yet only an approximation. It is, however, considerably more accurate than anything previously existing, and as more information is obtained we expect to definitely establish the chart for this type of airplane and to extend it to others for which this kind of information is of value.

The maneuverability data we are collecting are, of course, valuable from many other standpoints. I have purposely avoided any consideration of the structural problems of flight research, because they could not be treated properly in this short paper. I should like to point out, however, that this maneuverability work, and particularly the maneuverability studies being made on diving airplanes, supplies a valuable fund of information on airplane loads, since they include acceleration measurement. All of our results are studied from the structural standpoint as well as maneuverability.

TABLE 1—SOME RESULTS OBTAINED BY CHANGES IN MASS DISTRIBUTION, BALANCE AND WING-LOADING ON AN NY-1 AIRPLANE

	Service[a]	Altered[b]
Weight, lb.	2,390	2,900
Center of Gravity, per cent of mean aerodynamic chord	25.8	41.2
Inertia about x Axis, slug-ft.^{2}	2,380	2,376
Inertia about z Axis, slug-ft.^{2}	3,887	4,941
Radius, ft.	4.5	9.3
One Turn, sec.	2.5	3.5
Vertical Velocity, ft. per sec.	79	95
Recovery, turn	1	1
Angle of Attack, deg.	49	48
Sideslip, deg.	1	1

[a] Data in the first column apply to the airplane in its normal condition.

[b] Data apply to the airplane with the position of balance furthest aft and with the greatest spread of mass possible by means of the disposable load available

SPINNING INVESTIGATION

Knowledge of a quantitative character of the motion of an airplane in a spin and the forces acting on it is decidedly lacking. A few years ago we obtained some interesting information on spinning motion as a result of tests made with flying models constructed to scale both geometrically and with reference to the mass. We discovered, however, that for any dependable information, particularly with respect to the forces acting, we should have to go to full scale and therefore we have developed a method whereby all the elements of a fully developed spin can be determined. We have also devised, but not as yet used to any extent, a method for investigating the motion and the forces acting in the entry and recovery from a spin. I shall not go into detail here regarding the method employed, since a paper completely describing the method and computations is about to be published and will be available for those who are interested. It is sufficient to say that, by measurement of the angular velocities about three reference axes, the accelerations along these axes and the vertical velocity of the airplane, we are able to determine the flight path in the spin and the motion of the airplane along this path.

We have also developed an accurate method for determining the mass distribution of airplanes by means of swinging tests, and from this and the motion can determine the mass forces and moments acting during the spin. It is possible, therefore, to make a change in the airplane, as in the size of elevator or rudder or in the distribution of its mass or balance, and measure the results of such a change on the character of spin executed and on the forces and moments acting.

We are now in the process of determining the effect of change of mass distribution, balance and wing-loading on the spinning characteristics of a training-type airplane. While the work is not completed, Table 1 summarizes some of the results obtained to date. The data to the left apply to the airplane in its normal condition; those to the right are with the furthest-aft position of balance and with the greatest spread of mass that we were able to use with the disposable load available. The mass and balance were changed by means of load carried in tanks at the nose, center of gravity and tail, which could be dropped in flight if the airplane went into a dangerous spin. It will be noted that, while many of the characteristics were greatly changed, others, and notably the recovery, were unchanged, and our original hopes of producing a dangerous spin on this airplane by means of changes in the loading and balance have not been realized.

We have also completed flight tests with the tail-surface area greatly reduced. The results of these tests have not yet been worked up, so that, while we know from observation that the recovery and general dimensions of the spin were not greatly changed, I am unable to say definitely at this time what the magnitude of this change was. The particular airplane tested behaves very nicely in a spin and never has shown a tendency to stay in the spin. We intend to carry on the spinning investigation on an airplane with less satisfactory spinning characteristics and have obtained for this purpose an airplane that has been reported on several occasions as being difficult to recover from a spin.

Re-refining Crankcase Oil[1]

By Winslow H. Herschel[2]

Pittsburgh Section Paper

DRAININGS from the crankcases of motor-vehicles are worse than useless. Emptied into the sewer, they create danger of an explosion, and if burned on the city dump the dense, black smoke is a public nuisance. If a way can be found to use the drainings, it will remove the difficulty of disposing of them and also conduce to the conservation of the oil supply of the Country.

The author discusses the causes of deterioration of oil in crankcases and the attempts to avoid this by the use of air-cleaners, oil filters and oil rectifiers on motor-vehicles, and states that, while oil does not wear out mechanically, it is contaminated by dust and particles of metal, diluted by unburned ends of the fuel, forms a sludge of oxidized products and is affected by corrosion of the crankcase by sulphur compounds resulting from the combination of sulphur in the fuel with moisture due to combustion, during which hydrogen and oxygen unite and form water.

The question arises of how to treat the drainings to make good reusable oil as well as how to keep the oil in the engine in good condition. This involves the further question of whether the desire is to make a commercial product or one for the vehicle-owner's own use. The author deals mainly with the latter case and points out that, as color has no effect on lubricating quality, the trouble and expense of bringing back the color of the original oil is unnecessary. Furthermore, removal of the diluent may be a needless expense, since after use of the re-refined oil for some 200 miles of vehicle operation it will again reach a condition of equilibrium dilution; but, if removed, the diluent has some commercial value, and the viscosity of the oil can be controlled by regulating the percentage of light fractions distilled off in the re-refining process.

Three ways of bringing the oil back to its original color are (*a*) by treatment with sulphuric acid, (*b*) by percolation through fullers' earth, and (*c*) by mixing the drainings with a cheaper earth and extracting the oil by means of a filter-press.

Cost of re-refining varies, according to claims made, from 8 to 20 cents per gal. One commercial plant that brings used oil back to all the qualities of the original oil, including color, reports an average cost of 18.9 cents per gal. over a period of nearly one year and an average sale price of 25.7 cents per gal.

Answering questions in the discussion, the author states that asphaltic-base and paraffin-base oils are re-refined with equal facility and that no difference in method or apparatus has been found necessary in treating the different oils or mixtures of them. He states that equilibrium dilution seems to be governed by crankcase temperature, being higher in winter than in summer, partly due perhaps also to greater use of the choke in cold weather.

The discussion further deals with the most desirable viscosity of oils, how re-refined oils of heterogeneous origin compare with new blended oils for specific engines, the importance of service tests to determine the best type or viscosity of oils for a given type of service, kinds of acids formed in oils during use and their neutralization by alkali in re-refining, how re-refined oil compares in actual service with new oil, persistence of particles of clay in the re-refined oil as the result of the use of fullers' earth, the relation of color to "oiliness" and commercial apparatus marketed for re-refining.

THIS SUBJECT of re-refining, as I prefer to call it, has more than one angle. I say "re-refining," because the word "reclaiming" gives people a prejudice against the material. They think of shoddy goods, reclaimed rubber, and things of that kind, which are inferior; and if anyone says "reclaimed oil" they immediately jump to the conclusion that such oil is a poor oil. So I prefer to say that the process is re-refining instead of reclaiming.

In general, crankcase drainings are not only of no value, but are worse than useless. If an attempt is made to burn them on the city dump they make such a dense, black smoke that the neighbors complain. If they are emptied into the sewer they create danger of an explosion on account of the gasoline content, of which there is no ready way of getting rid. Therefore, if we can find a way to use the material, it will not only be conducive to the saving of natural resources, conserving our supply of oil, but will remove the difficulty of disposing of this waste product.

The Sewer Department of the City of Washington is much interested in this matter from the latter point of view and has passed a regulation requiring everyone who has waste oil to put it in a container and keep it until it is collected. The Department proposes to let a contract for emptying these containers, believing that in this way the oil can be kept out of the sewers much more effectively than by a negative regulation against disposing of the oil in the sewers.

In some places crankcase drainings are used to burn garbage. Drainings sell for 5 cents per gal. in New Orleans, where they are used in the war against mosquitoes; but in most places crankcase drainings are of very little use and people are glad to be saved the trouble of carting them away.

Causes of Crankcase-Oil Deterioration

In considering this question of re-refining crankcase drainings, we must bear in mind how crankcase oil deteriorates in use. I was responsible for the statement made a number of years ago, which has been widely quoted and criticized, that oils do not wear out. My original statement was that "oils do not wear out mechanically"; I did not mean that they do not deteriorate in use, for they do, but they do not wear out in the sense of wear in a rope, in which the length of fiber has been shortened and which cannot again be made as useful as when new.

In an automobile, the oil has added to it dust from

[1] Publication approved by the Director of the Bureau of Standards of the United States Department of Commerce.

[2] Associate physicist, Bureau of Standards, City of Washington.

the atmosphere, metal particles due to engine wear, and the heavy unburned portions of the fuel; moreover, the oil oxidizes in use, and if this oxidation goes far enough it forms a sludge, which is a combination of oxidized products, moisture, oil and dirt. We must remember that moisture is often present, because moisture is a product of combustion. If the fuel contains sulphur, this sulphur will combine with the water and form sulphuric acid, which will corrode the crankcase.

About ten years ago, attempts were made to develop rectifiers to put on automobiles to keep the oil continuously in good condition without removing it from the crankcase. This has proved successful in steam turbines but has not been very successful in automobiles; at least the idea has not been extensively adopted.

So the question under discussion is how to treat crankcase drainings to make good oil rather than how to keep the oil in the car in good condition. Much can be done to prevent rapid deterioration of the oil by the use of air-cleaners, oil filters, or purifiers on the automobile. Crankcase ventilation retards dilution to a certain extent, but in general we may say that virtually no automobiles now in use have oil rectifiers as part of their standard equipment, hence we have to deal with this used crankcase oil that contains not only dust, metal particles and oxidized oil, but also the unburned fuel.

Straining and Neutralizing

Obviously, the dirt must be removed. This can be done by straining; I dislike to use the word "filtration," which, unfortunately, is used in more than one sense. Filtration through fullers' earth gives a decolorized product because of the adsorption of the coloring matter upon the earth. The dust and metal particles can be removed by a system of straining, by settling, or more rapidly by centrifuging. Then it is generally believed that some alkali should be used to neutralize the petroleum acids that are formed in use. When we go much further than this, we come to differences of opinion.

Two distinct problems are presented in the re-refining of oil, according to whether the oil is to be re-refined for sale or for one's own use. I shall discuss more especially the problem of re-refining oils for the vehicle owner's own use, because the other problem is more or less one of refinery practice, which is rather outside of the field in which the Bureau of Standards is interested.

In re-refining oil for one's own use, the opinions or prejudices of the majority do not need to be considered except insofar as prejudices may influence one's own employes to the extent that they would not give an oil a fair chance if they thought it was not exactly what it should be; that is, that it did not meet certain specified tests that they believe an oil should meet.

Question of Removing Diluent

The first question that comes up is whether it is necessary to remove the diluent so that the oil will have the same viscosity and flash-point as the original oil. A great number of different types of re-refining apparatus are on the market. We know of perhaps a dozen different types, of all degrees of simplicity and effectiveness; and in making a selection the removal of the diluent is one of the first questions to be decided.

The principle on which the Isovis oils marketed by one of the leading oil companies are based is that the dilution of oils does not continue indefinitely, but, after perhaps 200 miles of use, they reach a stage of equilibrium and do not become diluted much further, although there may be a slight variation on one side or the other of a certain average dilution.

If this is the state of affairs, it is possible to predilute the oil, that is, mix with a sufficiently heavy oil some form of naphtha or kerosene or other mineral hydrocarbon to give it approximately the same composition as the oil in the crankcase after it reaches this condition of dilution equilibrium. According to this theory, it is not necessary to start with an oil that is too heavy for the first 200 miles so that it will be of the right viscosity after it has reached the state of equilibrium; one might just as well start with the prediluted oil and have it of the right viscosity from the start. I understand that, in recommending the grade of oil to be used, the automobile manufacturers take into account this normal amount of dilution, so that after the equilibrium has been reached the oil will have adequately high viscosity.

Therefore, it seems futile to remove the diluent in re-refining an oil merely so that the viscosity shall be too high for the first 200 miles and be correct after that.

However, removal of the diluent has certain advantages. There is the psychological effect on employes to which I referred, and the diluent has a certain commercial value. Some of it may be used for making penetrating oil and the rest for burning under the stills in re-refining. More important is the fact that the viscosity of the re-refined oil can be controlled by regulating the percentage of diluent or of light fractions that are distilled off. Difficulty would be encountered in getting just the viscosity desired, if a still were not used and the viscosity regulated by this means.

Methods of Restoring Light Color

One of the most difficult and expensive processes of re-refining is that required to bring back the color of the original oil. This can be done if necessary, but the extra cost of getting a light color will not be repaid by any savings on automobile repair bills. The ways most commonly used for getting this light color are (*a*) by treatment with sulphuric acid, which does not appeal to me very much, as it seems a rather bad method for use by those who are not specially trained as chemists; (*b*) by filtration through fullers' earth, which has been referred to; and (*c*) by the so-called contact process, in which an earth is mixed with the oil and then removed by a filter-press. The last method has an advantage as compared with the percolation process, or filtration through fullers' earth, as a greater variety of earths may be used, the cost of the earth therefore tending to be less.

The cost of re-refining obviously depends to a large extent upon whether the intention is to get as good a color as that of the original oil. Costs that have been claimed vary from about 3 cents to nearly 20 cents per gal. I have a report from a plant in Texas, which I assume is accurate, that over a period of about a year the average cost was about 18.9 cents per gal., and that the average sale price was 25.7 cents. Those figures are from a commercial plant, but nevertheless they give some indication of what could be done in a private plant. In this case the oil was brought back to the original color and every test ordinarily applied in the

laboratory indicated that the re-refined oil was as good as the original oil.

I do not know that I can agree with those who say, "Do not trust laboratory tests; trust service tests." It seems to me that to misinterpret service tests is as easy as to misinterpret laboratory tests; in fact, I am inclined to think it is a little easier, because the conditions in service tests are not as well controlled as they are in the laboratory, where one knows just what the conditions are and what the oil will do under those definite conditions. Therefore, I believe that there is good reason why a re-refined oil should be judged by the same tests as the new oil.

I have always thought that the ingredients used in making a finished product were no concern of the user; the only question in which he is interested is whether the finished product will do the work satisfactorily. For example, I never have had any sympathy with the idea that the user should specify just how much soap and just what viscosity of oil ought to be used in making a grease. It would be far better, I believe, to write a specification calling for all the tests to be made on the finished product, without attempting to inquire into the ingredients used. For the same reasons I believe that the time will come when the user will not care whether crankcase drainings or crude oil is used in making a lubricating oil, and the only question he will ask is, "What is the nature of the finished product?"

THE DISCUSSION

CHAIRMAN W. A. GRUSE[3]:—The paper is on the exceedingly practical subject of whether the oil that has been used in the crankcase is capable of being re-refined for satisfactory use. This subject has been discussed and investigated a great deal but very little work has been carried on, I believe, by independent and unprejudiced investigators.

Dr. Herschel is, I think, the leading authority on the subject in the United States; certainly he is the only one of whom I know who has conducted both practical and theoretical investigation on the subject. He has a distinguished record as a physicist in the Bureau of Standards and is well known in the field of petroleum and lubrication for his work of standardizing apparatus for measuring the viscosity and consistency of oils and his attempts to solve the very puzzling question of the property known as "oiliness," that is, just why a certain lubricant is the right one to use when another is not.

I am sure that it will be a pleasure for him to answer such questions as may arise and to amplify the contents of his paper with more direct information on specific points.

All Oils Alike in Re-Refining

B. H. EATON[4]:—Are all types or brands of oil, both those made from the naphthenic-base and the paraffinic-base crudes, subject to reclaiming or re-refining?

WINSLOW H. HERSCHEL:—At the Bureau of Standards we try to be fair and not take sides between oils from different crudes. We find it easy to be impartial because it is very difficult to prove that one is much different from the other. Apparently the naphthenic-base-oil companies have proved that their oil is better as regards carbonization in the cylinder, and the paraffin-base-oil companies have proved that pour-point does not mean as much as was supposed, because oil below the pour-point can be pumped quite readily.

In testing re-refining apparatus, we never bother about which oil we re-refine; in fact, on one occasion, we went to a filling station and pumped out of the sump the drainings from many cars and had no difficulty at all in re-refining the mixture. I do not see why any difference in the crude might make any difference in re-refining. We have no difficulty with mixed naphthene-base and paraffin-base oils; in fact, I understand that most of the oils on the market are a mixture of the two, and there is no known method of finding out whether one oil is mixed with, say, 10 per cent of the other base.

QUESTION:—What is the elemental base of the other oils? We know of naphthene and paraffin and asphalt bases.

DR. HERSCHEL:—Suppose we talk geography instead of chemistry; I think it will be easier to understand. A certain class of oils that come from Pennsylvania are ordinarily called paraffin oils. These have the smallest change of viscosity with temperature of any petroleum oils but have the disadvantage of high pour-point unless they are thoroughly de-waxed. The object in removing the wax is to lower the pour-point. The Oklahoma or Mid-Continent oils are intermediate between the Pennsylvania oils and the Gulf Coast Texas oils. The Texas oils are ordinarily called naphthene base, although my chemical friends tell me that they should be called asphalt-base oils. The naphthene-base or Gulf Coast oils have a larger change of viscosity with temperature than either the Pennsylvania or the Oklahoma oils.

QUESTION:—The element I want to get clear is the other base besides the naphthene and asphalt.

DR. HERSCHEL:—Petroleum oils are classified according to the series of hydrocarbons that predominates in them. The Pennsylvania or paraffin-base oils contain mostly compounds of the general type C_nH_{2n+2}. Russian oils contain a large percentage of compounds, usually called naphthenes (C_nH_{2n}), which are cyclic hydrocarbons of the polymethylene series. In the Gulf Coast Texas oils the series C_nH_{2n-2} predominates, but these are often called, without discrimination, either asphalt-base oils or naphthene-base oils. The name of the crude depends upon the chemical composition of the oil itself; it is not a question of the residue.

Anybody Can Operate Contact Process

QUESTION:—I have had proposals made to me by three different concerns that are manufacturing re-refining machinery. One of them uses a chemical process and the others a distilling process. Does the former require a real chemist to operate it? And can used oil be re-refined with any of this equipment so as to be as good as new oil?

DR. HERSCHEL:—If you do not want to re-refine oil

[3] M.S.A.E.—In charge of petroleum research, Mellon Institute of Industrial Research, Pittsburgh.

[4] M.S.A.E.—Motor-Vehicle supervisor, Bell Telephone Co. of Pennsylvania, Pittsburgh.

to sell and do not remove the diluent and try to bleach the oil, simpler apparatus can be used than if you tried to do both. For example, I think that anybody can operate the contact process, which is about as simple as any. The only thing to do is to mix the oil and the earth together, put the material in a still, heat it until the diluent is removed, then put it in the filter-press and separate the oil from the dirty earth.

MURRAY FAHNESTOCK[5]:—I have talked with some automobile dealers and with manufacturers of such apparatus about this subject and it seems to me that there are two lines of thought in the matter. One relates to a fleet of trucks, for example. Suppose a man owns 40 trucks of one make and uses one brand of oil in them. It would seem to be a simple process to re-refine that oil, and several manufacturers tell me that they can handle it with their apparatus. But they say that only one apparatus can handle mixed oils from the filling stations where the crankcases of all makes of vehicle are drained into a common sump. Have you any information with regard to that?

DR. HERSCHEL:—We have never found it necessary in our investigations to make any difference in the method of re-refining depending on whether it was one oil or a mixture of an indefinite number of oils. If the makers of that apparatus have made any statement regarding the reason why it will work with one oil and will not with a mixture of oils, I should be very interested to know the reason. Two reports that the Bureau of Standards has made on this work may be of interest. Both were published in the *Oil and Gas Journal*[6], of Tulsa, Okla. The first was on the contact process, in which we used oils that were all alike and oils that were an unknown mixture, making no difference in the process. Nor do I know of any reason why we should make any difference in the process or why any difficulty in the process should be caused by having the mixed oil.

MR. EATON:—Were the Washington tests made with special apparatus or apparatus made for commercial use?

DR. HERSCHEL:—One test was made with apparatus which was being developed partly at the Bureau; that employed the contact process. The designers had its development fairly well along but wanted a little further help, and came to the Bureau to finish the development, but to all intents and purposes that was a commercial apparatus. The other outfit was made for demonstration purposes. If that was any different from the commercial apparatus it probably would not be as good, because it was made on a smaller scale; but the Bureau did not put anything special on the apparatus to improve its operation.

Shall Diluent Be Removed?

A. R. PLATT[7]:—In a portion of the paper you seemed to question whether it is desirable to remove the diluent. Frankly, we do not know whether we do or do not want to, yet when we talk with the representatives of the reclaiming machines, and I have spent hours listening to them, they all claim to remove the diluents, acids and so forth. If we want to remove the diluent, why should there be any question?

DR. HERSCHEL:—The makers of re-refining apparatus have assumed, as a rule, that the market demands an apparatus that will remove the diluent. To make what the public demands is good policy, because when you do that you are most likely to be able to sell it. To sell the public something against which it is prejudiced is difficult and requires education of the buyers. It is hard enough to combat public opinion regarding the use of crankcase drainings, as the public calls the re-refined oil, and to convince oil users that they are as good as the new oil; that is why most of the makers of re-refining apparatus have taken for granted that they should make apparatus which would enable their customers to make a re-refined oil with as high a flash-point as the original oil.

A MEMBER:—I do not care about what the makers of the machines think. We try to remove the diluent because, when the operator purchases his oil, he wants an oil of a viscosity suitable to his purposes. When that oil becomes diluted to such a point that it is of no use as a lubricant, we feel that, to meet his requirements, we must remove the diluent to give back the body.

MR. PLATT:—If it is not proposed to remove the diluent or to change the color, probably the main requirement would be to get rid of foreign matter. In that case, why not use the simplest process of filtration rather than distillation? Would not distillation also remove the diluent?

DR. HERSCHEL:—I did not attempt to decide for anyone whether or not he should remove the diluent; I simply tried to start you thinking as to whether necessity for removing the diluent has been proved. If you do not want to remove the diluent, there seems to be no need of the still, but when you say "filtration" a question arises whether you mean a mere straining or whether you mean percolation through fullers' earth. The latter does bleach the oil, and if you do not want to bring the oil back to the original light color you need not go to the expense of percolation through fullers' earth. On the other hand, by filtration, you may mean flowing the oil through excelsior or canvas or something like that, which is not a decolorizing process but what I shall call straining.

Why Car Makers Urge Draining Crankcase

MR. PLATT:—Considerable misconception seems to exist in the minds of us men, whom I might call laymen so far as the oil industry is concerned, as regards removing the diluent. Our training has been that after the lubricating oil in an automobile engine has reached such a stage of dilution that it is advisable to drain the oil out, the process of re-refining the oil was rather a matter of removing the diluent. From all that we have been able to gather, removing the diluent seems to be highly desirable in order to restore the original viscosity.

DR. HERSCHEL:—If you do not remove the diluent you will have the original viscosity of the prediluted oil that I understand constitutes one-half the lubricating-oil product of the Standard Oil Co. (Indiana). However, there are two reasons why you are advised to remove the oil at the end of 500 miles or whatever the distance may be: not only does the oil decrease in viscosity with use, due to the diluent, but it becomes contaminated with more and more grit. If the oil is of high viscosity, it forms a thicker oil-film in the bear-

[5] M.S.A.E.—Technical editor, *Ford Dealer and Service Field*, Pittsburgh.

[6] See *Oil & Gas Journal*, Nov. 8, 1928, p. 144, and Nov. 21, 1929, p. 165.

[7] M.S.A.E.—A. R. Platt, Automobile Repairs, Pittsburgh.

ings, and this grit will not cause excessive wear because it can find a place in this oil film without rubbing on both the metal surfaces. As the oil becomes thinner with dilution, the oil film becomes thinner and more wear is caused by this grit.

Nevertheless, there is more or less absurdity in the matter. If it is true, as claimed, that after 200 miles the oil has reached an equilibrium dilution, no great advantage is gained in running for the first 200 miles with a higher viscosity and then running for a longer period with a constant lower viscosity; that is, as the higher viscosity obtains for only a portion of the time, there is not much point in draining out the oil of lower viscosity, except to remove the increased quantity of grit in the oil, which does cause damage at that lower viscosity.

Why Oil Reaches Equilibrium Dilution

MR. PLATT:—Does any one know just why the oil reaches a certain level of dilution in the first few hundred miles and whether there may be a way to prevent it? The manufacturers tell us that the dilution does come in the early stages and that beyond a certain point it does not get any worse, but our general automobile experience does not seem quite to bear that out. Perhaps light on the subject will lead us into a different channel of thought.

DR. HERSCHEL:—The point at which stable dilution is reached depends upon the crankcase temperature. We know that dilution is higher in winter than in summer, because of the lower crankcase-temperature and also because in winter there is an increased use of the choke, shorter runs and perhaps other factors that tend to cause dilution. In a discussion of oil rectifiers and crankcase dilution in 1926, W. G. Wall, who perhaps was not entirely unbiased, as he is the inventor of one of the rectifiers, made the following statement:

> This hypothesis is based on the fact that, when oil is put into a crankcase and run in an engine, the dilution will finally reach a certain equilibrium; in other words, when the dilution reaches a certain percentage, the heat of the crankcase will maintain the oil at that point of dilution. I think that would be very fine if this hypothesis were not entirely wrong. I have found that, although there may be such a thing as equilibrium in a crankcase in warm weather when the whole engine is rather hot, the longer it runs without a rectifier in cold weather, especially in short runs of from four to six miles between which it stops and cools off, the more will the dilution increase. The curve, instead of reaching a point at which it is perfectly horizontal, shows that the dilution will increase and continue to increase as long as the engine runs; that is, until it reaches such a point that it would make little difference to the parts whether it went higher or not.

To be fair, I think that is the best argument I can give on the other side, but you may notice that he says "in cold weather and short runs." I am quite ready to believe that under those conditions the oil would not reach a limit of dilution. One of my colleagues who lives near the Bureau complains that he does not live far enough away and that his engine does not get hot enough before he reaches the Bureau. That is a special case, and in those special cases the crankcase oil might never come to a state of equilibrium dilution.

Acids Neutralized with Alkalies

A MEMBER:—When the refiner of the asphalt-base oil uses sulphuric acid to destroy the last traces of asphaltum, would there be any tendency in using excelsior as a strainer to bring about a chemical reaction with the creosote and a number of other chemicals that are in some kinds of excelsior?

Another point is this, about two years ago one manufacturer of automobiles had considerable trouble because the action of moisture on the oil in the crankcase formed sulphuric acid that ate out the pins and an oil rectifier was installed. Will straining the oil through fullers' earth be sufficient to take care of that, or will the same trouble recur?

DR. HERSCHEL:—I do not know much about excelsior; I mentioned it as an example of a material that acts more or less as a sieve and would not act as a decolorizer on which the oxidation products were deposited. I was simply trying to think of something inert, without having in mind that excelsior is used in any particular re-refining apparatus.

A MEMBER:—I understand that it is.

DR. HERSCHEL:—With regard to the sulphuric acid, I mentioned that if alkali were used in the re-refining process it would neutralize sulphuric acid as well as the petroleum acid.

C. J. LIVINGSTONE[8]:—I was made acquainted with some work that had been done by one of the automobile companies which found out that it could prevent much of the sulphuric-acid corrosion by keeping the engine warm. The temperature of the block was maintained at 110 to 120 deg. fahr, and not much sulphur dioxide got into the crankcase; it went off in the exhaust.

Difficulty of Determining Correct Viscosity

NILS G. BJORCK[9]:—From the laymen's standpoint it seems to me that the different refining companies are spending a great deal of money to blend different types of oil to produce an oil for specific purposes. It seems to me, from what you have said, that their efforts to produce oils for specific purposes are all knocked into a cocked hat, and that they might take any old mixture and call it good. Is there any reason, from the original refiner's point of view, for blending oils to such a fine point as seems to be the practice today?

DR. HERSCHEL:—I am not quite sure whether the question refers only to viscosity or to other more or less esoteric qualities of oil that are known to the refiner but not to the consumer; but, assuming that it applies only to viscosity, I believe that the best viscosity for a given engine probably is not known within, let us say, 25 per cent, and that giving the exact viscosity within 1 or 2 points is perhaps exaggerating the matter quite a bit, because an automobile engine has many different bearings and a viscosity that is right for one might not be the best viscosity for another bearing operating under different temperatures and speed; different viscosities should be used for different temperatures and speeds.

Since the question has been raised, I shall show you what is known with regard to the correct viscosity for a given position. We know that if we take speed-X viscosity and divide it by the pressure, then plot the coefficient of friction against that ratio, we get a curve

[8] Jun. S.A.E.—Industrial fellow, petroleum fellowship, Mellon Institute of Industrial Research, Pittsburgh.

[9] M.S.A.E.—Chief engineer, Lange Motor Truck Co., Pittsburgh.

something like that in Fig. 1, showing that there is a speed of maximum friction, *b*. That is given in a book by Archbutt and Deeley, and is quoted by these Englishmen from the work by an American[10]. It is generally recognized that there is a definite speed of minimum friction, *c*, but if a bearing is run at that speed there is no factor of safety. There is danger of getting to the left of the point of minimum friction and having heating of the bearing; the heat increases and the viscosity of the oil decreases. So you have to stay some distance to the right of the minimum point, *c*, to assure comparative safety; the increase in the coefficient of friction above what it is at the minimum point is the price that has to be paid for an adequate factor of safety.

In some of these service tests that we hear about as being preferable to laboratory tests, care should be taken that someone does not give you an oil of lower viscosity which gives a lower friction but at the same time reduces the factor of safety. Just because you are getting a lower friction does not prove that one oil is better than another.

MR. BJORCK:—Is the viscosity of a new oil as recommended for a specific make of engine such that the oil must be used for, say, 200 miles before it becomes of the characteristic of re-refined oil, or have most of the oils the desirable viscosity before that degree of usage has been established?

DR. HERSCHEL:—I am informed that, in making recommendations for the proper viscosity to use for a given engine, the automobile manufacturers take into account what the viscosity will be after reaching equilibrium with a normal percentage of dilution; that is, they deliberately recommend an oil that has too high a viscosity until equilibrium has been reached.

Both Service and Laboratory Tests Needed

C. R. NOLL[11]:—Laboratory tests of motor lubricating oils define the quality of the oil and also furnish a guide to the right type of oil to be recommended for a given engine. As a result of block tests, oils are sometimes recommended that are quite light in viscosity. If too light an oil is recommended for service operation in motorcoaches or trucks as a result of block tests and an attempt is made to use this light-type oil after 50,000 or 60,000 miles of actual service of the engine, we do not get the sort of results expected as regards both consumption and lubrication. Therefore, in making recommendations, service tests of an oil must be considered along with actual laboratory and block tests. The type of service to which an engine is to be put has a great deal to do with the choice and weight of oil.

One point to be brought up in connection with prediluted oil is the fact that the condition of the engine has a great deal to do with the percentage of dilution after operation of the engine. We have made frequent tests of prediluted oils, knowing the percentage of predilution, and found that after service in the engine there was no dilution, the diluent being driven off by the heat and the type of operation of the engine. On the other hand, we have had tests made on an oil the original 15-per cent predilution of which has run up to 50 per cent, the percentage depending on the type of operation and the engine operating temperatures.

I understand that the work of re-refining crankcase oil at the Bureau of Standards has been more on an experimental basis rather than using actual reclaiming outfits as marketed today. Are any reclaiming outfits sold commercially today which actually use fullers' earth, either in a percolation process or a contact-filtration process, to clarify the oil?

DR. HERSCHEL:—Most of what Mr. Noll says agrees entirely with what I was trying to explain. In regard to his last point, I am not certain whether there are any processes that use fullers' earth, but I believe that in the original refining of crude petroleum there is a distinct tendency to discard the percolation through fullers' earth and to use the contact process instead, for one reason because a greater variety of earth can be used with contact processes. It is very largely a question of economy. I have no doubt that one is as effective as the other in producing an oil of good quality.

Removal of Products of Oxidation

W. E. CLARK[12]:—Will you tell us more about the oxidation of the oil in the crankcase, and the removal of the oxidation products afterward?

DR. HERSCHEL:—As a rule the oxidation products that form in the oils have two effects; they darken the color of the oil, and, if the process goes far enough, cause sludging. Crankcase oil always has a tendency to increase in viscosity due to oxidation, and the only reason that this is not noticed more is because it is counteracted by the decrease in viscosity due to dilution. If an automobile engine is run on aviation gasoline, the oil may become more viscous.

Some methods used for the removal of oxidation products remove dust by precipitation or by treatment with alkalies such as caustic soda, trisodium phosphate or washing powder, which remove the sludge together with the dust. If the oil is bleached so as to get a light color, the soluble oxidation products that give the oil the dark color will also be removed, and it is safe to assume that the oil will contain no more oxidation products than were present in the original oil.

Two Kinds of Acid Formed

MR. CLARK:—A question still remains in my mind concerning the contamination of the oil and the necessity of removing that. I have in mind the case of a car that is used occasionally and allowed to stand for several days at a time. It has been mentioned that certain acids get into the crankcase. This may not be noticeable in large amounts and to the inexperienced person the diluation would not seem to be sufficient to cause any harm, yet after a while the engine will begin to knock, and upon examination the piston-pins will be found to be rusted. We believe that this has been caused by an acid condition of the oil. If we do not remove this acid in re-refining the oil, the condition will continue.

If used oil can be re-refined as simply as Dr. Herschel seems to imply, it looks as if oil companies might be put out of business, for they have always advised us very strongly to change the oil every 500 to 800 miles according to the type of engine used. A number of years ago we used to add a quart of oil now and again for the engine, but with the type of engines used today we all advise filling the crankcase, driving so many miles and then draining all the oil out and adding fresh

[10] See Lubrication and Lubricants, third edition, p. 61; quoting Kimball in *The American Journal of Science*, 1876.

[11] M.S.A.E.—Automotive lubrication engineer, Gulf Refining Co., Pittsburgh.

[12] E. S. Carpenter, Inc., Pittsburgh.

oil. In my opinion that will do away with most of the acid that has accumulated.

DR. HERSCHEL:—I have not said a word against draining all the oil out of the crankscase after 500 miles or any other mileage. All I have said is that it is not necessary to throw it away after it is drained out; it can be re-refined.

We have to make a sharp distinction between two kinds of acids; there is sulphuric acid, which results from sulphur in the fuel combining with moisture and is a mineral acid. Mineral acids are very much more corrosive and more active than petroleum acid. We also have petroleum acids or naphthenic acids, which ordinarily are formed at the same time as solid asphaltic oxidation products. I do not say that all oils will develop acid and asphaltic compounds in the same proportions, but almost every petroleum oil will to a certain extent develop both asphaltic compounds and an acid. These petroleum acids, however, are very mild as compared with the sulphuric acid, and we believe that the naphthenic acids have not, in many cases, become sufficiently concentrated to cause corrosion. At any rate, if an alkali is used in the process of re-refining, it will neutralize both the mineral and the petroleum acids.

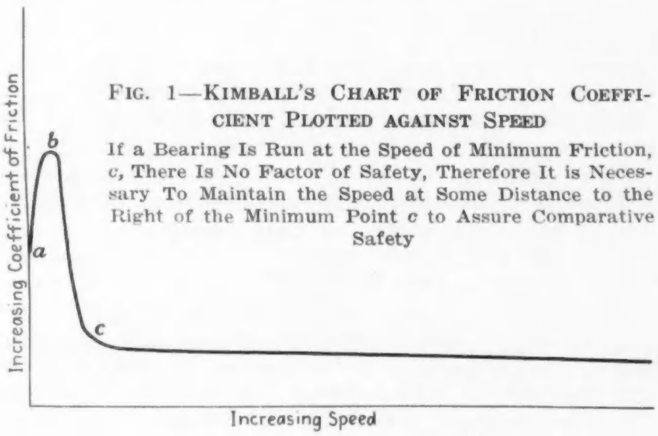


FIG. 1—KIMBALL'S CHART OF FRICTION COEFFICIENT PLOTTED AGAINST SPEED

If a Bearing Is Run at the Speed of Minimum Friction, c, There Is No Factor of Safety, Therefore It is Necessary To Maintain the Speed at Some Distance to the Right of the Minimum Point c to Assure Comparative Safety

Results Obtained with Re-Refined Oil

J. A. HARVEY[13]:—In your tests with different engines, have you noticed any difference in the wear as between a new oil and re-refined oil? Would you recommend the use of re-refined oil from the start, feeling sure that the engine would not wear any more than with a new oil?

DR. HERSCHEL:—I cannot answer definitely from actual tests I have made, but I am convinced that there is no reason why one should anticipate any difference in the properties of the new oil and the re-refined oil. If there is supposed to be any difference that would lead you to expect more wear in one case than in the other, I should be much interested to know what properties of the oil are supposed to be different and by what method of test the difference can be detected.

I have made no road tests myself but I hear repeated claims of tests that have been made which show that re-refined oils are distinctly better than new oils. Seyer and Allen, in a report[14] on laboratory tests that they made on both used oils and new oils, state their conclusion that used oils, when re-refined, would be superior to new oils because the more unstable compounds would have been subjected to oxidation and subsequently removed in the re-refining process. The claim seems to be entirely reasonable, because we know that if an oil is subjected to oxidation in the engine of an automobile the more unstable portion of the lubricant will be oxidized, and if the oxidized products are removed the remaining oil should be more stable, more durable, than the original oil.

I have heard of road tests in which a car has run 4000 miles without change of oil and the viscosity at 210 deg. fahr. was reduced only 3 Saybolt sec. I cannot guarantee that to be correct, but that is the kind of results that are reported with re-refined oil.

A taxicab company in the City of Washington has not bought any new oil for two years. Of course, it cannot obtain the same volume of re-refined oil that it drains out of the crankcases. Investigations in Washington have shown that about 13 gal. of oil is used per year per automobile, and of this quantity 5 gal. is available as crankcase drainings. Of this 5 gal. somewhere between 50 and 75 per cent, depending upon the process used, can be recovered as good oil. There is the question of make-up. Instead of buying new oil for make-up, the taxicab company collects crankcase drainings in the city to add to its own used oil for re-refining. This has gone on for two years.

MR. BJORCK:—If the re-refined oils are of superior quality, does any engine manufacturer recommend them for use in his new engines?

DR. HERSCHEL:—Because a thing is good does not necessarily mean that the automobile manufacturers can be convinced of the fact over night and will recommend it. If you will remember, the S.A.E. numbers for lubricating oils, which I think anybody here will admit are a good thing, have been talked about for a number of years and yet it has taken considerable effort on the part of the Society to induce the oil refiners to put the S.A.E. numbers on their cans and the car manufacturers to recommend the use of oils by S.A.E. numbers. How soon people are going to recommend re-refined oil is a question; such things do not happen over night.

Objection to Use of Fullers' Earth

CHAIRMAN GRUSE:—I think you mentioned fullers' earth for bleaching oil and for removal of the soluble oxidation products, but I do not know of any reclaimers who make a practice of using fullers' earth, and I certainly believe not many of them do.

DR. HERSCHEL:—Probably you are right, but I understand it was used for Nujol.

CHAIRMAN GRUSE:—The thought I have in mind is this: The common experience among the refiners is that, if the oil is mixed with fullers' earth or fine clay which is then removed by a filtration operation, a slight trace of the earth remains in the oil. In the refinery the stills gradually become coated with clay and burn out, and in the laboratory we find that a very small quantity of inorganic material does stay in the oil. Perhaps you can suggest some means of eliminating that clay which sticks to the still and remains in the oil.

DR. HERSCHEL:—The persistence of clay in the oil is an interesting fact that has come to my attention in connection with the Synder life-test for transformer

[13] M.S.A.E.—Operating engineer, Pittsburgh Motor Coach Co., Pittsburgh.

[14] See *Industrial and Engineering Chemistry*, August, 1929, p. 793.

oil. Briefly, this test consists of oxidizing the oil at a moderate temperature until precipitation occurs, the life of the oil being measured by the number of days that elapse before this precipitation can be detected. With some oils the difficulty arises that after a very few days there is a white precipitate. After that there seems to be no more for quite a number of days, then by any by there is a black precipitate, and that keeps getting worse and worse.

My belief is that this white precipitate is due to precipitation of clay, which in the colloidal state remains in suspension as long as the oil is not acid, but the minute the oil becomes slightly acid due to oxidation, this clay is precipitated. That is not an oxidation product, correctly speaking, because the clay was in the oil before the test was begun, but it is confusing because it is difficult to distinguish between this primary precipitation of the clay and the secondary precipitation of the true oxidation products. If I am correct in assuming that this is clay, that would illustrate what Dr. Gruse referred to as clay that remains in the oil. If clay does remain in an oil, the question would be whether it is coarse enough and in sufficient quantity to cause abrasion in an engine.

Saving Claimed in Lubrication Costs

C. F. KELLS[15]:—I want to ask a question to learn, not how to do, but whether to do or not to do. This is the annual alibi period, and, in checking over some income statements of motorcoach operation, I find, in a total of about 7,000,000 coach-miles per year, an average cost of about 4 mills per mile for lubricant, including all lubricants. The question that has come to us invariably is, Can a sufficient change be made in that 4 mills per mile by using re-refined oil, considering the fact that new equipment is required, natural losses in the garages are variable, the interest on investment in both building space and the equipment itself, to make it worth while at present market prices?

DR. HERSCHEL:—I might answer that if a man is satisfied it is a pity to say anything to him that will change his mind; but if anybody wants to try to save money he might be interested in the remarks[16] of G. S. Doeller, whose claim is that "We saved 67 per cent of lubrication costs on our motor-transport fleet." I might add that he re-refined oil by a process that gave him an oil which was dark in color, a fact that caused him some anxiety at first, but his conclusion was that it did no harm and that he had saved 67 per cent of lubrication costs.

QUESTION:—In your opinion, is it necessary to restore the color in order to obtain a re-refined lubricating oil of the same quality as the original oil?

Color No Index of Lubricating Value

DR. HERSCHEL:—That seems to be a direct challenge. I have long been interested in this question of color. Wells and Southcombe have been granted a patent covering the putting of fatty acid into the oils, and I have no doubt that it is an excellent idea, because in my own "oiliness" machine I can get a very substantial reduction of friction by the addition of fatty acid; but Wells and Southcombe have another patent that perhaps is not so well known. They say that a certain percentage of the unsaturated compounds should be left in the oil when refining so as to avoid over-refining and get good oiliness. So I have been very much interested in trying to find out, by tests on my oiliness machine and otherwise, whether there is any such thing as over-refining and whether a white oil is necessarily inferior to colored oil in regard to oiliness.

I might explain that oiliness is the characteristic of importance in overcoming friction under conditions of high pressure and low speed. For example, lard oil, I think everybody will admit, has better oiliness than petroleum oil of the same viscosity. I have on many occasions tried to find out whether there was any difference in the coefficient of friction of a white, a yellow and a red oil, and every time I have failed to find any difference. Finally, I attacked this subject from an entirely different point of view. We oxidized some automobile oils by the Sligh oxidation test. That made a dark oil which would not pass specifications as regards color, but I tested this oil on the testing machine, which showed a lower coefficient than for the original oil. Therefore I came to the conclusion, that, theoretically, Wells and Southcombe were right; in other words, theoretically it is necessary to make a compromise between the oil that is best as regards oiliness and the maximum durability obtainable with highly refined oils. But, practically, there is no difference, because any oil that is light enough to be considered would have the same coefficient of friction, the same oiliness, as an acceptable oil of any other color.

I have gone so far as to test white oil in combination with yellow and red oils, and have detected no difference in the coefficient of friction. At one time I thought that kerosene was an example of over-refining, but further investigation showed that that was not the case. The trouble with kerosene is that it is of too low molecular weight. Hardy, in England, states that the higher the molecular weight—which is virtually the same as saying the higher the viscosity—the better the oiliness. Kerosene is too low in molecular weight to give a low coefficient of friction.

[15] M.S.A.E.—Assistant to the president, West Penn Electric Co., Pittsburgh.

[16] See *Railway Purchase and Stores*, September, 1928, p. 509.

Symposium *on* Aircraft Fuels

Necessary characteristics of fuels for the most reliable and economical operation of aircraft engines continue to be a moot question. Because of the importance of the subject, a special session on aircraft fuels was held at the 18th National Aeronautic Meeting of the Society in Chicago in August, 1930, at which the six papers that follow were presented. These were prepared and delivered by W. A. Parkins, representing an airplane-engine manufacturing company; E. W. McVitty, representing an airline operating company; S. D. Heron, representing the Army Air Corps; and C. M. Larson, E. E. Aldrin, and James H. Doolittle, representing oil-refining companies. A brief abstract precedes each paper and general discussion on the subject, both prepared and oral, is printed following the last of the papers.

Requirements *for* Large Air-Cooled Engines

By W. A. Parkins[1]

SOME fuels marketed as aviation gasoline cause temperatures in large air-cooled cylinders 300 degrees higher than in normal operation. Piston trouble has frequently been found to result from detonation caused by such fuels.

Pyrometers have not been common in the past, but now they are available at reasonable cost for instrument-board installation. Many oil companies lack adequate apparatus for determining knock values. The Pratt & Whitney Aircraft Co. maintains a limited testing-service to determine experimentally the suitability for aircraft engines of fuels that are submitted.

The author urges the recognition of a high standard for undoped aviation gasoline which shall be available throughout the Country. The addition of 2 cc. per gal. of tetraethyl lead to such a fuel will make possible a change from 5:1 to 6:1 in the compression ratio of large engines, with a corresponding increase in brake mean effective pressure from 130 to 135 lb. per sq. in. It is believed that any increased cost of the fuel will be offset by better economy, and that flying will be made safer in addition.

CONTROL of cylinder temperatures in service undoubtedly is the biggest problem before the manufacturer of relatively large air-cooled engines. Under the best conditions of full-throttle operation, these temperatures remain from 75 to 100 deg. fahr. below the accepted limits of safety, but poor engine-installations in airplanes result in temperature increases of as much as 150 deg., and the use of some fuels marketed for aviation purposes is responsible for increases of 300 deg. beyond those of normal service. Although considerable latitude is permissible in the operation of the engine, once these factors are brought up to acceptable standards, particular care must be exercised in the use of the mixture control and regulation of the throttle for safe and economical performance under abnormal conditions of cylinder cooling. Operating companies frequently overlook the possibility of lowering the gross fuel-consumption of their engines as much as 10 per cent, with no sacrifice in engine reliability or performance, by changing to the best grades of aviation fuel that are commercially available.

The maximum cylinder-temperatures consistent with successful operation depend on materials and cylinder design. The relation of measured to maximum temperatures depends on the position of the measuring elements. Since all of the air-cooled engines having piston displacement greater than 1000 cu. in. that are now in service are of similar design and employ the same materials, and since experience and good practice have established a standard method of obtaining temperature readings, measurements of 300 deg. fahr. for the lower end of the cylinder barrel and 500 to 550 deg. for the rear side of the head have been generally accepted as the upper limits for safety.

Often the statement is made that the manufacturer should design and produce his engine to operate below the safe allowable temperatures at all times. This could be accomplished with ease were it not for the basic requirement of any sort of air transport, that is, maximum horsepower per pound of powerplant weight without sacrifice in mechanical reliability. To meet this demand, the output of the engine is increased to an extent such that, with reasonable care in operation and with the better grades of fuels commercially available, it will operate at or below its rating with an ample margin of safety.

The resultant brake mean effective pressure is usually between 120 and 130 lb. per sq. in. at full throttle and 90 to 100 lb. per sq. in. when throttled to normal cruising speeds. Were it permissible to limit the maximum torque to the same value as the cruising torque, the quality of the fuel would cease to be of importance. It has been shown in recent laboratory tests that, with

[1] Experimental engineer, Pratt & Whitney Aircraft Co., Hartford, Conn.

no change either in compression or in the design of a standard air-cooled cylinder, ordinary grades of furnace oil can be burned successfully at brake mean effective pressures below 100 lb. per sq. in. without the addition of antiknock agents.

Cylinder Size and Compression Limit Fuel

Another factor to be considered in dealing with the fuel problem is cylinder size. At present, there seems to be little likelihood that the displacement of the conventional air-cooled cylinder will be increased beyond its present maximum of about 210 cu. in. Other things being equal, a cylinder of the size will generally operate about 50 deg. hotter than one of half this size and

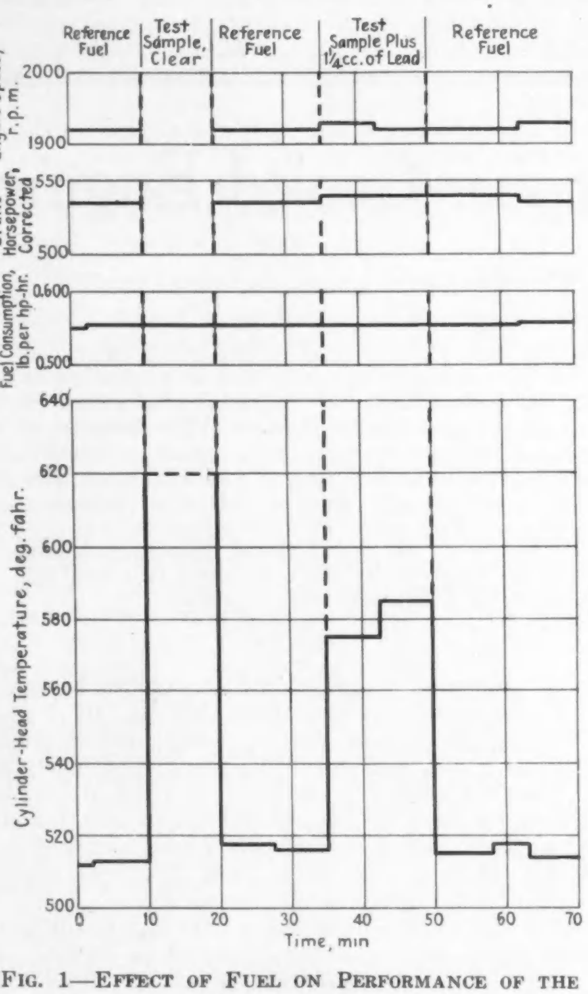


FIG. 1—EFFECT OF FUEL ON PERFORMANCE OF THE HORNET ENGINE

This Was a Full-Throttle Test Divided into Five Periods. Reference Fuel Was Used in the First, Third and Fifth of These Periods and the Fuel under Observation During the Second and Fourth Periods. During the Second Period, in Which the Clear Test-Sample Was Used, the Temperature Was Increasing and the Speed and Horsepower Were Not Constant

therefore will require a better grade of gasoline. However, the complications involved both to the refining and the engine companies in distributing more than one grade of aviation gasoline makes it seem inadvisable to market any fuel other than that suitable for use in the larger cylinder.

Compression ratio is a third major factor to be considered. Due, principally, to the lack of suitable gasoline, the compression ratio of air-cooled engines in the past has been kept below $5\frac{1}{4}$:1. However, as progress is made in fuel development, there seems reason to believe that compression ratios will be increased, with still further improvement in thermal efficiency and cylinder cooling. Once detonation is suppressed, the average reduction in cylinder-head temperature resulting from an increase in compression ratio of from 5:1 to 6:1 is in the neighborhood of 50 deg. fahr., a gain of considerable importance.

Therefore it is apparent that fuel plays an important part in the successful operation of the relatively large high-output air-cooled engine suitable for military or transport use. Although it accounts for less than 10 per cent of the total cost of systematic airplane operations, fuel is considered by many to be the most important factor of dependable service. The Pratt & Whitney aircraft records show that the majority of piston troubles are directly traceable to high temperatures resulting from detonating fuel.

Results of Poor Fuel Demonstrated

Fig. 1 shows for comparison the cylinder temperatures of an engine, under identical conditions of operation, while burning a good and a poor aviation fuel. The inferior gasoline was used until recently by a certain large transport company which experienced considerable piston trouble in its engines. Fig. 2 shows the results of detonation on a normal-compression piston after 6 min. of full-throttle operation. The fuel used during this run was a widely distributed domestic aviation gasoline, refined from mid-continent crudes. The temperature of the cylinder-head during the test mounted to 800 deg. fahr., only 200 deg. below the plastic point of the alloy.

The results of the use of unsuitable fuel are not always appreciated by either the refining company or the operating company, probably because, without the aid of temperature indicators, its effect on performance is not usually apparent during the operation of the engine. Furthermore, trouble from detonation is particularly difficult to recognize, as it is usually confused with failures developing from more tangible sources. As suitable pyrometer equipment was lacking until recently, the operators were without aid in determining cylinder temperatures. However, moderately priced instruments are now commercially available, and they should come into general use and rank in importance with other instruments regularly employed in flight operations. Their adoption will no doubt be of great assistance in controlling cylinder temperature.

Also, the majority of oil companies are without the facilities for converting the relative knock-value of gasoline into terms of engine performance and, without this information, market their products under the Grade B domestic aviation gasoline specification without regard for cylinder temperatures. However, my experience has been that, once convincing information in the form of reliable engine-test data is furnished to a refining company, a determined effort is usually made to improve the quality of the fuel to the satisfaction of the engine manufacturer if improvement is necessary.

Routine for Testing Gasoline

For this reason, the Pratt & Whitney Aircraft Co. maintains limited free service in testing gasolines and encourages both the refining and the operating companies to submit samples for test. Each fuel submitted

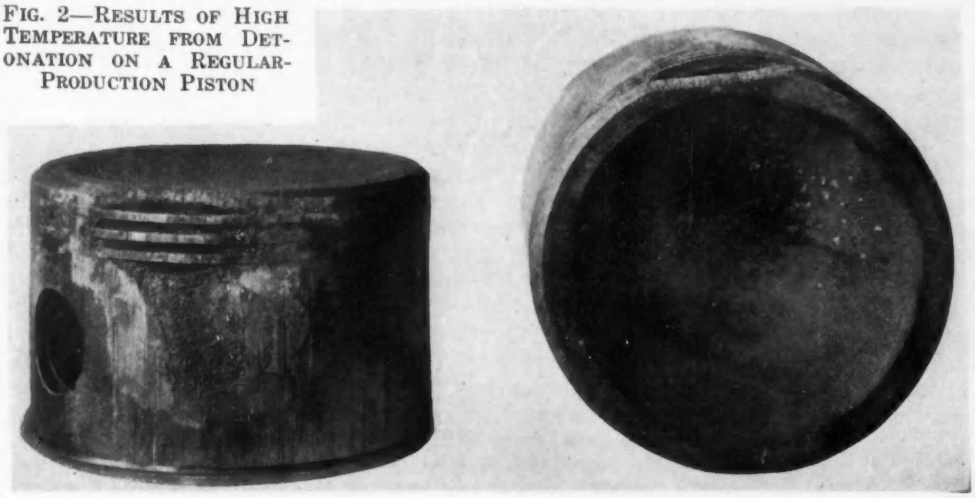


FIG. 2—RESULTS OF HIGH TEMPERATURE FROM DETONATION ON A REGULAR-PRODUCTION PISTON

is run in a standard-production engine under as nearly normal conditions as possible. Full-throttle brake-horsepower, speed, specific fuel-consumption and temperatures of all cylinders are measured. The engine is first run on the gasoline used regularly for all standard tests and known from long usage to be suitable for continued full-throttle operation. After approximately 15 min. of running, or until the cylinder temperatures have become constant, the fuel supply is changed to the test sample and the run is continued without shutting the engine down or in any way changing the positions of the engine controls or the cooling blast of the propeller. After these data are taken, the fuel is again changed to the reference gasoline and the performance of the engine is checked to make reasonably certain that conditions of operation have not varied during the test. The results are made available to the refining company that markets the fuel and to all operating companies using or considering the use of it.

The fuel to which test samples are compared is a domestic aviation gasoline, refined from Gulf and West-Texas crudes and blended with 2 cc. of tetraethyl lead per gallon. According to Navy standards, it has a highest useful compression ratio of 5.78:1, but when compared in a multicylinder engine it is slightly superior to straight-run fuels meeting these specifications. When examined in the series-30 knock-testing apparatus, it is found to conform closely to the Ethyl corporation's tentative standard, but in actual service it is somewhat inferior. The quality of this fuel, insofar as it affects cylinder temperature, is no better than is necessary for satisfactory full-throttle operation of the large air-cooled engines in service today.

Therefore it is proposed that a standard of knock quality somewhere between the knock requirements of present Navy and Ethyl Gasoline Corp. standards be adopted. Furthermore, it is proposed that all aviation gasolines should meet or exceed this standard without the addition of knock-retarding agents. The fact that one large refining company has already made known its intentions to market an undoped gasoline of quality equal to this in all sections of the Country is sufficient evidence to show that this is not setting an unattainable goal. Those companies producing gasoline of the superior grade will undoubtedly, of necessity, receive the engine-manufacturers' indirect support in marketing it.

Once the engine builder is assured of suitable fuel in all sections of the Country, he will immediately increase the compression ratio of his engine or by other means reduce still further the specific weight of the power-plant. Aviation gasoline will then find itself in the same relative position that it is today and will again require the use of antiknock compounds in quantities which experience has shown not to be detrimental to the engines.

Limited Use of Ethyl Is Not Harmful

The opinion that tetraethyl lead in limited quantities is harmful to the valve gear, which exists particularly among the operating companies, is probably based more on early than on recent experience. The Pratt & Whitney Aircraft Co., in all of its engine tests during the last three years, has purposely used an ethylized gasoline so as to observe its effect on the engine parts with which it comes in contact. Under normal conditions of operation and with proper care in storage, concentrations of 2 cc. of tetraethyl lead per gallon of gasoline have been found to result in no serious trouble. Very little experience has been accumulated by this company on greater lead concentrations.

The relative ineffectiveness of benzol at high temperatures eliminates it from consideration as a knock-retarding agent. Fig. 3 shows in comparison the effect on cylinder temperatures of benzol and tetraethyl lead in a mid-continent and in a California gasoline. It

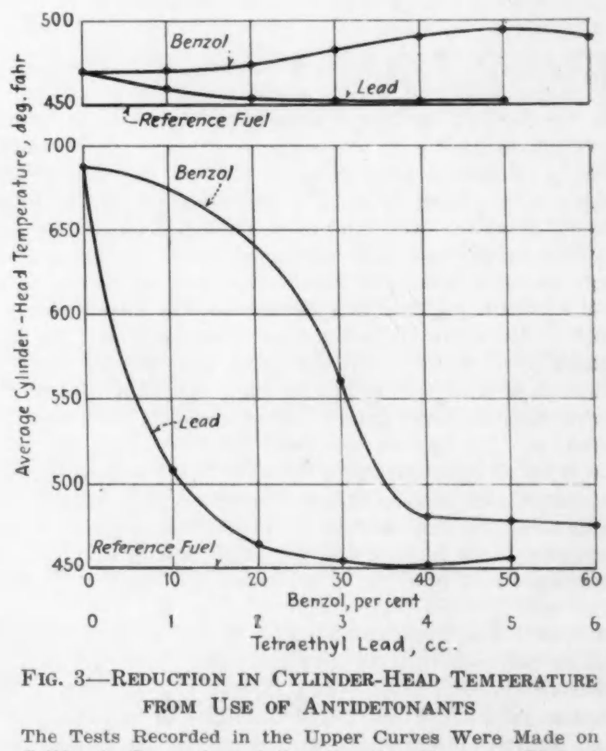


FIG. 3—REDUCTION IN CYLINDER-HEAD TEMPERATURE FROM USE OF ANTIDETONANTS

The Tests Recorded in the Upper Curves Were Made on California Domestic Aviation Gasoline Having a Highest Useful Compression-Ratio of 5.8:1. The Lower Curves Are Based on a Mid-continent Domestic Aviation Gasoline

will be seen that the inferior fuel requires 40 per cent of benzol to effect the same temperature reduction as 1½ cc. of tetraethyl lead. The addition of 10 per cent of benzol to a certain fuel, made necessary by the requirements of the Navy 5.8 h.u.c.r. test, went unnoticed when the clear and blended gasolines were compared in a service engine under identical conditions.

While undoped fuel of the quality recommended is suitable for the large 5:1-compression air-cooled cylinder when developing a maximum of 130 lb. per sq. in. b.m.e.p., the same fuel blended with 2 cc. of tetraethyl lead per gallon is satisfactory for the 6:1-compression cylinder at 135 lb. per sq. in. b.m.e.p. Engines of the latter compression-ratio and output are now being furnished to the military organizations and will probably be put into commercial service as soon as fuel conditions permit.

Still further progress in this direction is to be expected, but it awaits the recognition of an acceptable standard of knock quality under which aviation fuels shall be generally marketed. Then the chief cause of excessive cylinder-temperature will have been eliminated, and engine reliability will be increased as a result. With lower temperatures go reductions in parts replacements, engine overhauls, and general maintenance and fuel costs. The expense of producing the superior fuel may at first work a hardship on some of the refining companies and force an increase in the selling price in certain localities; however, in all probability, the increase in cost will be more than absorbed by the savings from decreased fuel-consumption. In the final analysis, air travel will be made safer and more economical and therefore more profitable for all concerned.

The Aircraft-Fuel Problem

By E. W. McVitty[1]

DIFFICULTIES encountered in airplane operation in tropical countries include changes that occur in gasoline during transportation, handling and storage such as condensation of water, evaporation losses that may cause a considerable change in the distillation range, gum formation, changes in knock rating, gum and corrosion, the last apparently having a catalytic action that accelerates gum formation.

Specifications that were decided upon after an 18 months' series of tests of samples from various refueling stations as representing a gasoline that was desirable for the equipment used and the operating conditions are given. They conform practically with the Government Domestic Aviation Gasoline Specification except for a maximum gum-content of 10 mg. instead of 3 mg., a distillation range lying between that of the Fighting Grade and that of the Domestic Aviation Grade and the additional provision for a knock rating of not more than 5 on the scale of the Standard Oil Co. of New Jersey.

IMAGINE 13,000 miles of airline with 37 refueling stops, many of which are several weeks distant by the fastest surface transportation from the nearest distribution-point of aviation gasoline. Imagine the variety of means that must be utilized to supply these points with fuel—railroad, steamship, sailing schooner, trucks, wagons, carts and even donkeys' backs; and the various containers that are used—tank cars, tin cans, large storage tanks and small underground tanks. Think of the amount of handling necessary, the unreliability of much of the labor in Latin American countries, the high humidity of some localities and the intense heat of others and you will begin to have an idea of some of the conditions that cause Pan American Airways fuel problems. To buy an excellent grade of aviation gasoline from an oil company's refinery is an easy task for a consumer, but transporting this same fuel many thousands of miles and storing it for several months, and at the same time having the gasoline consistently of the same excellent quality, is attended by many difficulties all of which must be overcome.

Under these conditions, a fuel at the airport where it will be pumped into an airplane may be of an entirely different quality than when it left the refinery. The changes evidently take place during the entire journey from refinery to airport and seem to be particularly accelerated by too much handling and also by storage under unfavorable conditions.

Changes That Occur in Gasoline during Transportation, Handling and Storage

In climates where the humidity is often very high, keeping gasoline free from water at all times is impossible. If the gasoline is stored in drums, which become heated during the day, the gasoline and vapor or air expand, and some of this vapor is forced out through the bung hole, even though this is tightly closed with a screw plug. During the night the drum cools off, the gasoline and vapor or air inside contract, and the air is drawn in from the outside. This process is repeated over and over again, and little by little moisture from the air which has been drawn in during the breathing process condenses inside the drum and, of course, collects in the bottom. If water has collected on top of the drum around the bung hole, it will, of course, be drawn into the drum, instead of air, by the partial vacuum when the drum cools off. Condensation of water in the gasoline container takes place in this manner, no matter what kind of a container is used, whether it be large or small storage tank, drum, case or airplane tank. The drums seem to collect more water, however, than do any other types of container. Underground tanks, although larger than drums and containing a larger percentage of vapor and air and although fitted with vent pipes, do not col-

[1] Assistant to the divisional engineer, Pan American Airways, Inc., Brownsville, Tex.

lect such a large percentage of water as drums, possibly because they remain at a more even temperature on account of being buried several feet in the ground.

Presence of dirt in gasoline is not nearly such a common occurrence as water, although now and then dirt may enter the gasoline through careless handling. When drums are stored for a considerable time, the water that enters them may produce sufficient corrosion to impart a muddy appearance to the gasoline and to form sediment.

Loss due to evaporation of course takes place during the breathing process described above, and to eliminate this loss entirely will probably never be possible. Again, drum storage seems to be the poorest method in this respect, especially if the drums are stored in the open and are exposed to the rays of the sun. Storing drums in the sun is only a temporary measure that is used until more adequate facilities can be secured, as evaporization losses may run as high as 3 per cent per month. Evaporation often causes a considerable change in the American Society for Testing Materials distillation of a gasoline but almost never enough to make any difference in the operation of the engines.

Gum forms much more rapidly in gasolines stored in drums under tropical conditions than it would in the same gasoline in bulk storage in a more temperate climate. When drums corrode, this corrosion seems to have a catalytic action that accelerates gum formation. A gasoline-benzol mixture also seems to form gum faster than pure gasoline even though the gum content of the benzol is entirely satisfactory at the beginning of the storage period.

We have not had extensive experience with the use of cracked gasoline, but such experience as we have had makes us reluctant to use this product. As much as 200 mg. of gum by the copper-dish test-method has been found in cracked gasoline after storage of two or three months, although less than 3 mg. was present when the gasoline left the refinery. Unfortunately, no tests were being made at that time for pre-formed gum so that no data are available as to the amount of gum actually present in the gasoline at the time of test.

Gasoline is sometimes found which fails to pass the copper-dish test for corrosion, especially when a benzol blend is used. Sometimes this gasoline apparently has no injurious effect whatsoever on the engines or fuel tanks; at other times serious corrosion of the jets and other parts of the carbureters was found with such gasoline at the end of even 50 hr. of operation. The gasoline referred to had an average sulphur-content of about 0.04 and never over 0.09 per cent.

Although few consumers seem to realize this fact, the knock rating of the same brand of gasoline will often vary considerably unless the refiner takes great care to control this quality. Changes in knock rating also occur after the fuel has left the refinery as is shown by the fact that samples of the same gasoline taken after distribution at different points and after the gasoline has undergone different storage conditions show different knock-ratings. This difference is usually not great enough to cause any practical difficulty, unless the knock rating of the original gasoline happened to be on the border line between satisfactory and unsatisfactory fuel. As the above refers to straight-run gasolines, explaining the difference in knock rating is difficult.

[2] See S.A.E. JOURNAL, January, 1930, p. 31.

Pan American Airways Specifications for Gasoline

When Pan American Airways first started operating, our policy was to buy the best quality of gasoline that could be secured at the various fueling stops. At that time Domestic Aviation Grade B Gasoline could be secured everywhere, but the antiknock value was not sufficiently good for it to be used without the addition of benzol. Strenuous efforts were constantly exerted toward obtaining an improved quality of gasoline. For over 18 months, samples of gasoline have been periodically taken from the various fueling stations and tested through the courtesy of several large refiners. By carefully studying these test reports, especially with reference to actual performance in service, we have been able to come to certain definite conclusions with respect to the kind of gasoline that we consider desirable for use in our particular types of equipment and under our own operating conditions. We consider these specifications merely as representing a fuel that has been found entirely satisfactory for our purposes. We do not consider that these are the best specifications for such requirements and, of course, hope to improve them. Furthermore, these specifications are not presumed to be suitable for all types of even commercial equipment or under all varieties of operating conditions.

The specifications for the gasoline used on the Pan American Airways system are those of the Government for Aviation Gasoline, Domestic Grade. However, several modifications and slight changes of these specifications, as listed below, have been made. Because of the unusual storage-conditions encountered, the gum content has been changed to the maximum of 10 mg. instead of the 3 mg. required by the Government.

The distillation range has been modified and lies somewhere between that for Fighting Grade Gasoline and for Domestic Grade. It is as follows, the temperatures being maximum except in the case of the initial boiling-point where a range is given. A requirement that has been added is the one for knock rating, which shall not be greater than 5.0 on the Standard Oil Co. of New Jersey's scale.

Initial Boiling-Point, deg. fahr.	105–120
Volume Evaporated	
5 Per Cent, deg. fahr.	155
50 Per Cent, deg. fahr.	212
End Point, deg. fahr.	335
Minimum Recovery, per cent	97

Copper-Dish Test for Gum

The Pan American Airways realizes as well as anyone else the shortcomings of the copper-dish test for gum. For our purpose, however, we have not been able to find a better substitute.

A study of data shows that the quantity of gum supposedly deposited in the intake manifold cannot be predicted from the copper-dish test.[2] A further study of these data, however, indicates that if the copper-dish gum-content is sufficiently low, the quantity of gum deposited will be negative. In other words, many gasolines showing a fairly high copper-dish-test gum-content will not deposit gum in the engine; whether any gasoline that shows a low copper-dish gum-content will deposit objectionable quantities of gum in actual service is very doubtful, however. Some investigators claim to have found such gasolines, but probably their occurrence is very rare. Moreover, the probability that gasoline

showing a low copper-dish gum-content will form undesirable quantities of gum in storage is very small.

If the copper-dish test were discontinued, a test for pre-formed gum and an accelerated-aging test would have to be substituted. All of the accelerated-aging tests so far devised are relatively much more expensive to run than the copper-dish test and would consequently not be practical for an airline to use in running a large number of routine check tests.

The copper-dish test is, therefore, the most desirable one from the point of view of airline operators, although it is not so desirable from the point of view of the refiner. However, we feel that the copper-dish test does not work a hardship on the refiner in our case, as all the gasolines we use at present are straight-run products, and a refiner should have no difficulty in making a straight-run gasoline that will show less than 10 mg. of gum according to the copper-dish method.

Lately the merits of some kind of a copper-strip test at low temperature as compared to the copper-dish test for corrosion have been discussed at some length. We have been unable to find conclusive proof, however, that corrosion troubles are never experienced with fuels passing some kind of copper-strip test. Unless some form of copper-strip test is demonstrated to be clearly superior to the copper-dish corrosion-test from the point of view of the operator, for the operator to include an additional test in his routine test-procedure would be foolish, as the copper-dish corrosion-test has already been made after the copper-dish gum-content has been found. Serious corrosion has been experienced with fuels that failed to pass the copper-dish test for corrosion, and we have no evidence that the corrosive action increased with the age of the fuel.

Knock Rating

The requirements of any operator with respect to knock rating are that the fuels used have a high enough antiknock value to give satisfactory engine-performance under the most-severe operating-conditions that are encountered. This value will, of course, be different for different types of engine, different installations of the same engine in various types of ship and different atmospheric conditions, especially with regard to temperature. We have found that the most severe conditions which we encounter in this respect are when one engine of a multi-engine airplane fails during flight, and the remaining engine or engines must be operated at or near full throttle. This is the criterion for the knock rating of all gasoline that we use.

A gasoline with a good knock rating will, of course, produce lower engine-temperatures than will a fuel with a very poor knock rating. A certain point, however, exists beyond which the engine temperatures for a given set of conditions will not be reduced by using a fuel with a better knock rating. The results of many flight-tests, using many different brands of gasoline and operating the equipment that we use under the most severe conditions peculiar to our lines, indicate that this knock rating is about 5.0 on the scale of the Standard Oil Co. of New Jersey when tested at a jacket temperature of 212 deg. fahr. As has been said before, these conditions represent wide-open operation of the remaining engine or engines when one engine has failed in flight. Unfortunately, test flights at air temperatures much greater than 90 deg. fahr. have been impossible, but encountering temperatures much greater than this in flight along the Pan American Airways system is extremely rare.

In addition to requiring a knock rating of 5.0, any gasoline used for the first time by Pan American Airways is given a flight test, comparing it with fuel that has given satisfactory service over a long time. Such tests are conducted by filling one airplane tank with the gasoline to be tested and another tank with a fuel that is known to be of satisfactory quality. Thermocouples are attached to the rear spark-plug gasket of the No. 1 cylinder, which contains the master rod, on one engine of a two-engine ship or of the center of one outboard engine of a tri-engine. This point, for all practical purposes, can be taken as the hottest point on the entire engine. The airplane is then flown at a constant altitude, about 1000 ft., and at cruising speed on one gasoline and notations of the head temperatures and of all engine and flight instruments are made every 3 to 5 min. or oftener. The airplane is then operated under the same conditions on the other gasoline and notations are made for the readings of all instruments. One engine is then throttled back and the remaining engine or engines opened to full throttle. The two gasolines are then compared as above under these conditions. If the gasoline being tested does not cause a permanent rise in the engine temperatures under any of these conditions, its antiknock value is satisfactory. We have noticed that any change from one fuel to another while in flight often causes a slight rise in engine temperature, even when changing from a fuel of poorer to one of better knock rating, but this temperature rise is only temporary, and the temperature soon settles down to a constant reading.

This flight test is used as a precautionary measure in case some fuel should be found whose knock rating as tested in the laboratory did not give the correlation in engine performance as expected. So far, these correlations have been especially good, and in only one case has a gasoline been found which produced temperatures under operating conditions which were not expected beforehand. In this case, the temperatures were about 25 deg. higher than were expected at full-throttle operation.

The fuels we use produce cylinder-head temperatures of from 400 to 425 deg. fahr., when the remaining engine or engines operated at full throttle with one engine throttled back, and the temperatures will, of course, run considerably lower at cruising speed when all engines are in operation. As Wasp engines can be operated for long periods with head temperatures in excess of 500 deg. fahr., the above figures afford an ample margin of safety. Head temperatures are used to determine the antiknock value of fuels under flight conditions, because a temperature rise is noted long before audible detonation occurs.

Distillation

The Pan American Airways distillation specifications were drawn up before the significance of the 10 and 90 per cent points and the insignificance of the initial and end-points were generally realized. The foregoing specifications on distillation represent gasoline that has been found to be entirely satisfactory over a long period of operation. We realize the inadequacy of our distillation specifications but do not wish to change them until we are sure of the exact specifications that would best suit our requirements. Considerable research

work has been done on volatility specifications and on correlating such specifications with service performance in automobiles, but very few data are available which correlate laboratory tests with service performance in aircraft engines.

Specifying a gasoline that will not cause vapor lock nor poor distribution for a given type of equipment under given operating conditions is possible. The exact limits for these requirements are much more difficult to specify, however, and moreover, insufficient data are available showing a specific effect of distillation range on such important items as power output and fuel consumption. The lack of such data can undoubtedly be attributed to the difficulty and expense of procuring the necessary information. Extensive programs of flight testing would be entirely too expensive for any commercial airline to undertake, and a conservative operator would hesitate to experiment with new fuels on a scheduled passenger run. Aircraft operators are badly in need of the data outlined above and they would greatly appreciate the assistance of some organization technically and financially in a position to render it.

Benzol and Tetraethyl Lead

We have used and are using benzol along various portions of our lines. Although benzol has often proved far from ideal, its use has always seemed to be the best solution of each particular antiknock problem as it arose. When benzol was first used along our lines, tetraethyl lead had not reached its present stage of development. Now, the only division using benzol also uses a few engines designed several years ago which prohibits the use of lead.

Securing benzol that would pass the copper-dish corrosion-test in a 15 per cent benzol-gasoline blend has always been difficult, even though the benzol would not discolor a copper strip immersed in it for 3 hr. at 122 deg. fahr., and although the sulphur content of the benzol was less than 0.09 per cent. As previously mentioned, gasoline-benzol mixtures have been found to have a greater propensity toward forming gum when stored in drums under conditions of excessive heat and moisture, although the gasoline was of a straight-run variety, and although gasoline and benzol had satisfactory gum-contents at the beginning of the storage period. One instance was encountered where a 20 per cent benzol-gasoline mixture caused deterioration of the rubber-hose connections in the fuel system of the airplanes. In spite of these difficulties, we have been able to secure satisfactory benzol, and engine temperatures even under severe conditions, when using gasoline-benzol mixtures, have been entirely satisfactory as the figures given indicate.

Steps Taken To Insure a Supply of Satisfactory Fuel

The heart of the entire fuel-inspection system of the Pan American Airways is its own fuel-testing laboratory at Miami, Fla. This laboratory is fully equipped to run routine tests for corrosion, gum content, sulphur content, knock rating and distillation and also such other special tests as may be required from time to time.

The knock-rating apparatus is a Series 30 engine built by the Ethyl Gasoline Corp. The base fuels and testing procedure used are the same as those of the Standard Oil Co. of New Jersey, and knock rating is therefore expressed in the same scale.

A 1-gal. sample is immediately forwarded to the Miami laboratory from each new lot of gasoline, as soon as it is received by the oil company's local agent at each of the various refueling points of the Pan American Airways system. As an adequate supply of gasoline is always stored at the airport in these various localities, enough time is available for the samples to be tested before the fuel from the new shipment is actually used. If the test report of the gasoline sample indicates that it should not be used, this information is transmitted by radio, and a new supply of fuel is sent to the particular locality in question at the earliest possible moment. Routine samples are tested within 24 hr. of the time when they are received by the laboratory.

In view of the adverse conditions prevalent in many localities, the failure of a particular sample to meet the requirements is not necessarily to the discredit of the refiner. The various refiners, however, have always cooperated fully in such cases by making a new shipment of gasoline to the points in question immediately.

In addition to the sample from each shipment, a 1-gal. sample of the fuel actually on hand at the airport is taken once each month at each station. This is an additional safety precaution to insure that no unusual conditions cause a radical change in the quality of the gasoline between the time it leaves the warehouse of the oil company's local agent and the time when it is ready to be pumped into the tank of the airplane.

Precautions against Water and Dirt

Where fuel is pumped from drums directly into the airplane tank, the end of the pipe of the hand pump which is carried into the drum is several inches from the bottom. Any water or dirt that may be present in the drum has collected in the bottom, well below the end of this pipe, and, therefore, does not pass through the pump. For the same reason, the outlet line of the underground tank is several inches from the bottom. Underground tanks are thoroughly cleaned at regular intervals so that the accumulation of dirt and water is not allowed to reach the bottom of the outlet pipe. In fueling airplanes, a funnel of special design, which is provided with a fine-mesh screen and a water trap, is used. A chamois of the very best grade is clamped inside this funnel.

The tanks of each airplane are filled as soon as the plane reaches its overnight station. This provision leaves less air space above the gasoline in the tank, and less breathing and consequently less condensation takes place. To eliminate the danger from such condensation as does occur, the sumps of all gasoline tanks are drained at the end of each 10-hr. run, and the fuel strainers are drained immediately before every trip. In addition to these precautions, each airplane tank is thoroughly flushed out and cleaned at the end of each 50 hr. of operation.

Personnel

Three engineers of the Pan American Airways are charged with the specific duty of studying all fuel problems and data possible, constantly adding to the company's general knowledge of fuels and making continued improvements in all matters pertaining to fuel. One of these engineers is located in New York City, and his special duty is to gather as much information as possible from outside sources. With this end in

view, he attends technical meetings, gathers published data and maintains close contact with fuel specialists of other organizations. The other two engineers are located at two divisional headquarters where they may correlate data from test reports with information obtained during actual operation of the engines and also with the conditions of the engines when they are dismounted for overhaul. One of these engineers is in charge of the fuel-testing laboratories. At various times special flight-tests are conducted under the supervision of a divisional engineer to gather specific information.

The Pan American specifications alone are not responsible for the success we have had with gasoline. Full credit must be given the various oil companies concerned. They have realized our needs and their responsibility in meeting them in a most gratifying manner.

Diversity *of* Fuels Demanded

By C. M. Larson[1]

DEVELOPMENT of an improved fuel at a reasonable increase in cost is held by the author to be necessary so that engine manufacturers will be in a position to offer better engines. But how far and how fast this improvement in fuel can be made depends upon economical distribution and the standardization of engine manufacturers' requirements.

The gallonage of aviation gasoline distributed to airports and flying fields is relatively small and five groups of aviation interests demand as many sorts of fuel. The general desire, however, is for a fuel having a suitable antiknock value, the complicated situation being brought about by differences of opinion as to how to arrive at it. The first step to be taken, suggests the author, is to raise the permissible gum-content from 3 mg. to at least 20 mg. per 100 cc., so that refiners will not be restricted to producing straight-run aviation gasolines. If a standard specification were worked out for one gasoline having a reasonably high antiknock value, to be used for scheduled transport, aerial service and private flying, and not more than one additional specification for a fuel to be used by the Army, the Navy and such transport lines and other consumers as desire to use superchargers and who must use compression ratios higher than 5.1:1 for air-cooled engines, improved fuels would be developed as a natural course by the refiners to meet these needs.

THE QUESTION of suitable fuel for private and commercial aircraft purposes has been widely discussed during recent months throughout the United States, as everyone interested desires to do away with the necessity of fitting fuels to the various makes of aircraft engine instead of stopping at the building of engines that will operate satisfactorily on the standardized fuels that are available at present throughout this Country.

From the fuel producer's standpoint, the development of an improved normal fuel at a proportionate yet reasonable increase in cost is necessary so that the engine manufacturers will be in a position to offer an improved product. How far and how fast this improvement in the Domestic Aviation Gasoline Grade B, as specified by the Federal Specifications Board in the Department of Commerce Technical Paper 323B (see appendix), can be made depends upon the economic distribution and availability of the product as well as upon the standardization of the aircraft-engine manufacturers' requirements.

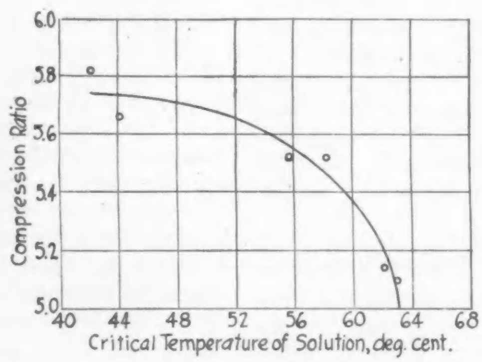


FIG. 1—CRITICAL TEMPERATURE OF SOLUTION IN ANILINE PLOTTED AGAINST COMPRESSION RATIO

The Chart Is Based on Data from Various Gasolines Throughout the Country and Shows that, with the Navy Specification Requirement of a Compression Ratio of 5.8:1, the Critical Temperature of Solution of 40 Deg. Cent. Could Be Applied to the Old Army Specification 2-40-F To get the Navy Antiknock Value

Analyzing aviation-gasoline consumption figures for 1929, it is found that for other than Army and Navy requirements, the gallonage dispensed was as follows:

Private Flying	3,774,000 gal.
Aerial Service	15,760,000 gal.
Scheduled Transport	3,059,000 gal.

The 19,534,000 gal. dispensed for private flying and aerial service was distributed by 20 major companies, approximately five of which have National distribution. Most of the transport companies operating on schedule have standardized on one type of gasoline, stipulating definite quantities and places of delivery, much the same as the Army and the Navy do in contracting for their requirements.

If the gallonage used by the 6114 airplanes operating under active licenses and comprising the private flying and aerial service were equally divided among the 1218 airports dispensing it, the quantity would be 15,800 gal. per airport per year; but, when it is estimated that 250 airports do 60 per cent of the gasoline business, it will readily be seen that many flying-fields which are widely distributed handle only a very small

[1] M.S.A.E.—Supervising engineer, Sinclair Refining Co., New York City.

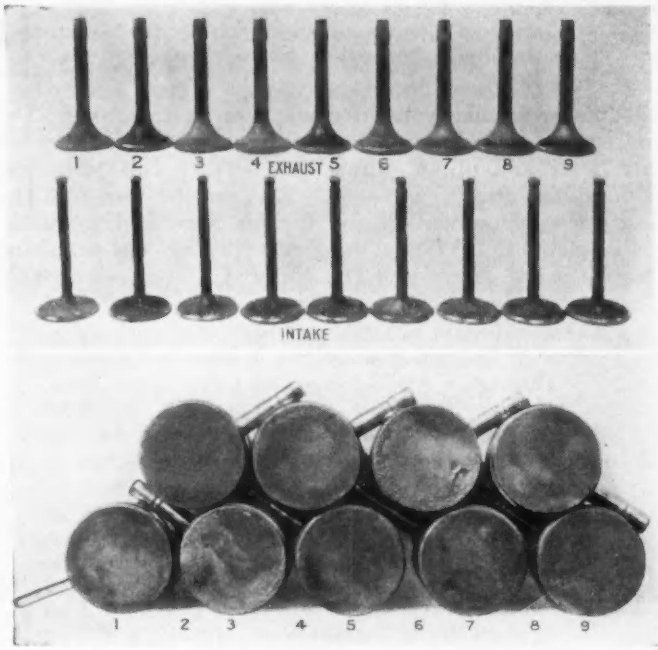


FIG. 2—VALVES AND PISTONS REMOVED FROM WRIGHT J-4 ENGINE AFTER 70 HR. OF OPERATION ON DOMESTIC AVIATION GASOLINE CONTAINING 40 MG. OF GUM PER 100 CC. BY THE COPPER-DISH TEST

No Trouble Was Caused by Deposits of Gum or by Sticky Valves

proportion of this gallonage. By way of contrast, compare these figures with the 26,600,000 motor-vehicles and their annual consumption of 15,000,000,000 gal. of gasoline.

If aviation gasoline were of one standardized grade, such as the U. S. Motor Fuel now being sold for land vehicles, the problem would be simple; but, when the field is split into five groups necessitating the carrying on hand of several grades of aircraft gasoline for such a limited demand by such widely scattered dispensers, economic complication sets in and the petroleum refiner is discouraged because of the small special-gasoline runs that are necessary to take care of these diversified requirements. Because of the small gallonage dispensed through these numerous fields, shipments to warehouse points are in most cases handled in drums in carload lots rather than in tank cars. Dispensing

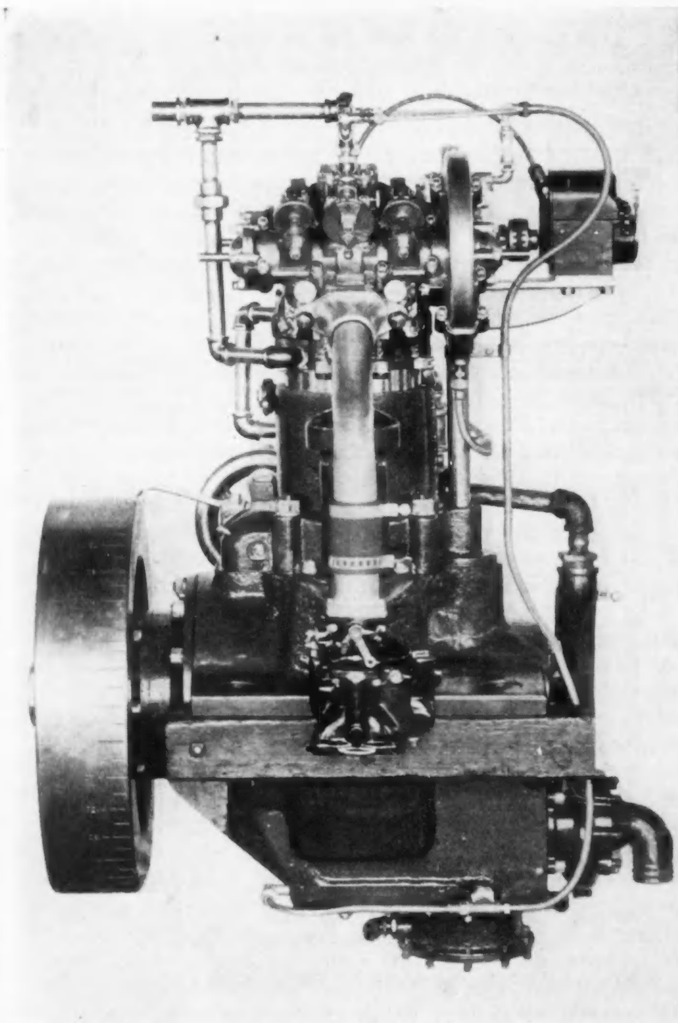


FIG. 3—NAVY ENGINE FOR GASOLINE TESTING

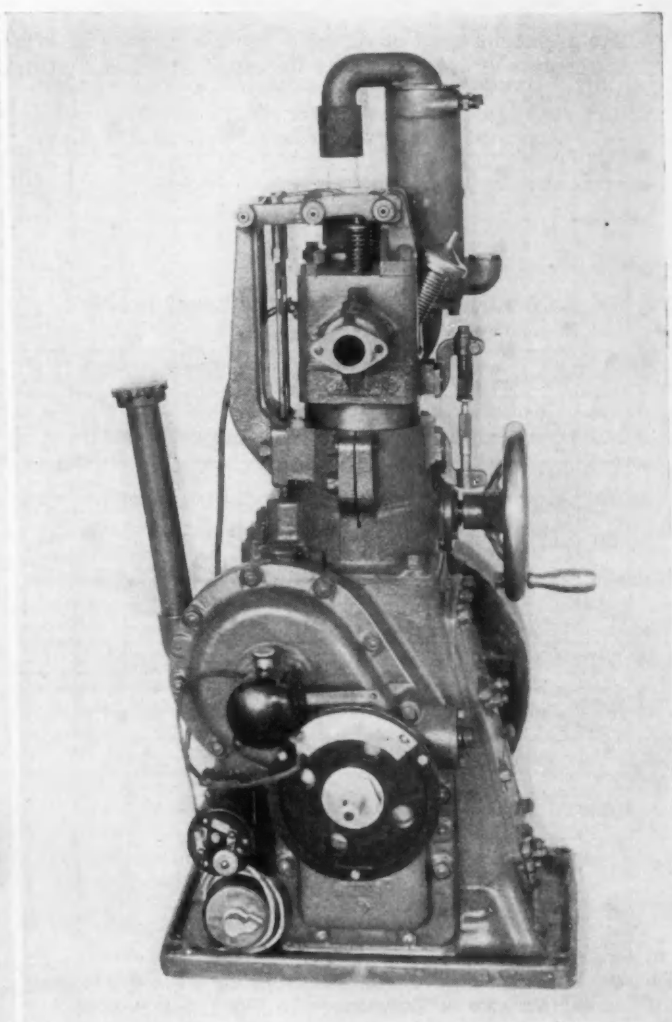


FIG. 4—COOPERATIVE FUEL RESEARCH COMMITTEE KNOCK-TEST ENGINE

Provision Should Be Made, According to the Author, for Maintaining the Jacket Cooling-Temperature Constant at 300 Deg. Fahr.

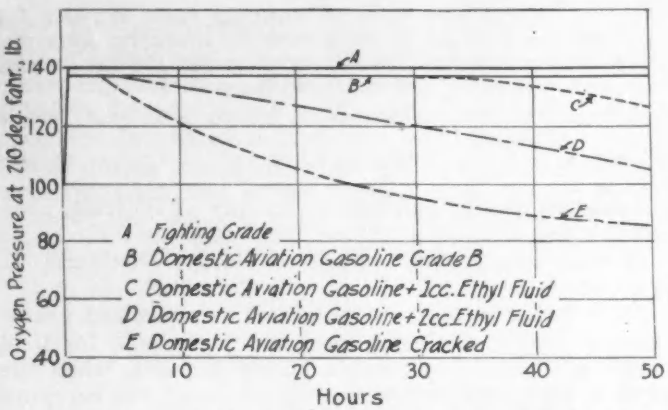


FIG. 5—OXIDATION STABILITY OF AVIATION FUELS

The Curves Show, by the Drop in Oxygen Pressure at 210 Deg. Fahr., the Tendency To Form Gum in Storage. A Drop at 5 Hr. Is Equivalent to Approximately 6 Mos. in Storage

gasoline to airplanes from such drums is not at all satisfactory, this method having been regarded as hazardous during the World War because of condensation of moisture in the drums and the contamination that is certain to occur.

Sources of Demands for Five Grades

The apparent need or demand for five grades of aviation gasoline developed from five separate and distinct sources:

(1) Suppliers or designers who follow the Department of Commerce Specifications for Aviation Gasoline, Domestic Grade (Technical Paper 323B)

This group, desirous of giving recognition to the Department of Commerce and its control of licenses of airplanes and pilots, wants to consider this specification sufficient for its needs. The specification was the natural development of the former Specification 8G1b, dated Sept. 1, 1917 (see appendix), which was standard for both the Army and the Navy Air Services in this Country during the World War.

(2) Engine builders who, desiring a higher-compression aviation gasoline, have been influenced by the Army Air Service and U. S. Army Specification No. 2-40-F (see appendix), and insist on the use of this modified Domestic Aviation Gasoline Grade B to which is added 2 to 3 cc. of tetraethyl lead per gallon

(3) Engine and aircraft builders who, being of the same mind as those in Group (2), but feeling that aviation ethyl gasoline is the cause of deposits, corrosion and sticky valves, have found, like the Navy, that West Coast gasolines made to meet Navy Department Specification 7G1c Grade B (see appendix), have an antiknock value equal to that of aviation ethyl gasoline

This specification calls for an antiknock compression-ratio of 5.8:1 as determined on an N.A.C.A. Universal variable-compression engine (cooling-water tempera-

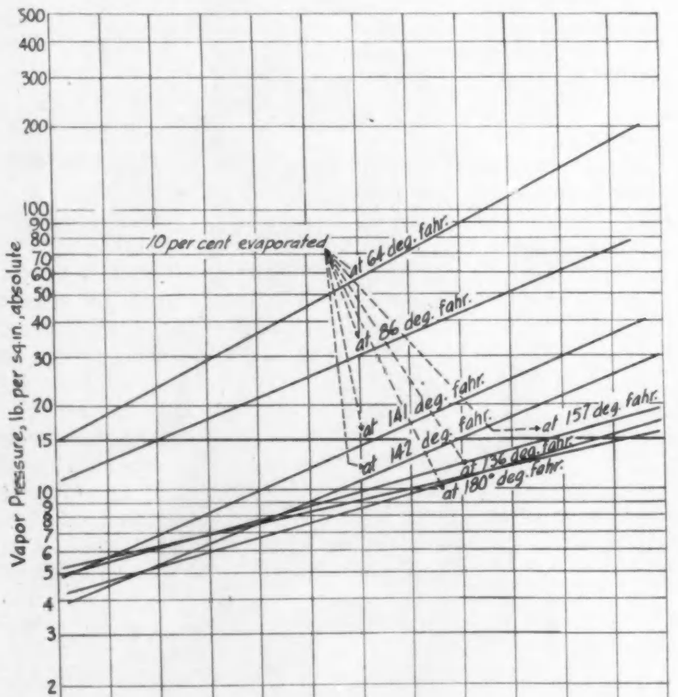


FIG. 6—VARIATION IN VAPOR PRESSURE OF FUELS OF CORRESPONDING AND OF DIFFERENT 10-PER CENT POINTS

Note That Two Fuels Having Virtually the Same 10-Per Cent Points Have 15 Lb. Vapor Pressure at Considerably Different Temperatures and that Two Fuels of Different 10-Per Cent Points Have the Same Vapor Pressure at 100 Deg. Fahr. but Reach a Pressure of 15 Lb. at Substantially Different Temperatures

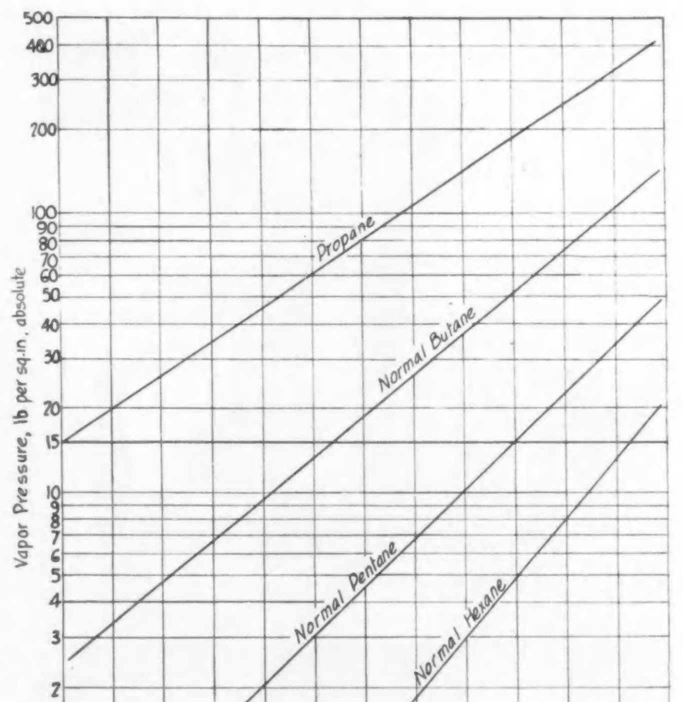


FIG. 7—VAPOR PRESSURE OF PETROLEUM CONSTITUENTS

Propane Has a Vapor Pressure of 15 Lb. per Sq. In. at a Temperature of —80 Deg. Fahr. and, by Forming Gas at Very Low Temperatures, Readily Causes Vapor Lock and Should Therefore Be Removed in Refining. Normal Hexane Requires a High Temperature To Reach 15 Lb. Vapor Pressure and Reduces the Tendency of a Gasoline To Cause Vapor Lock

ture 180 deg. fahr.). This in reality amounts to adding to the Department of Commerce Aviation Gasoline Domestic Grade a critical temperature of solution not to exceed 44.0 deg. cent., as shown by Fig. 1.

(4) Commercial concerns and engine builders who recommend Aviation Gasoline, Domestic Grade, as does Group (1), plus 15 to 20 per cent of benzol to secure the required antiknock value

(5) Those who sponsor another compromise fuel, which is the Fighting Grade or the 329-end-point Aviation Gasoline (see appendix) offered. not only because of its lighter weight per gallon than the Domestic Grade, but also because of its better antiknock value.

Desires Similar but Opinions Differ

Analyzing the various specifications as required by the foregoing five groups, it will be seen that the first four have distillation range, color, doctor, acidity and sulphur requirements identically the same. Therefore, what has really caused this situation, complicated as it is, is a general desire for a suitable antiknock value yet a difference of opinion as to what method shall be adopted or dope used to arrive at it. The lack of understanding as to just how much a universally distributed product can be raised in antiknock value without a price increase to airports of more than 3 to 5 cents per gal. over the tank-wagon price of U. S. Motor Gasoline has added grief to the situation.

It would seem that the first step to take would be to raise the gum content of aviation gasoline from 3 mg. to at least 20 mg. per 100 cc. A 70-hr. test made on 48-mg. aviation gasoline showed no trouble due to deposits or sticky valves (See Fig. 2), and several aviation gasolines sold today having a gum content in excess of 50 mg. apparently are giving satisfactory service. If refiners were allowed a gum content of 20 mg., they would not be restricted to producing straight-run aviation gasolines. Straight-run methods are obsolete today in making fuels for motor-vehicles because such gasolines have a low antiknock value.

With regard to the antiknock rating, if we are going to use either the Navy gasoline test-engine or the knock-test engine of the Cooperative Fuel Research Committee, illustrated in Figs. 3 and 4, some provision should be made whereby the jacket-cooling temperature can be maintained at 300 deg. fahr., which temperature seems to be desirable for aviation-gasoline testing.

Raising the permissible gum-content may allow gum to build up too fast in storage. Fig. 5 shows the oxidation stability, by the Ethyl Gasoline Corp. bomb test, of several aviation fuels conforming with the Navy specifications and the manufacturer's specification given in the appendix hereto. This method could be used to safeguard against deterioration. The curves, however, show that whatever is done to raise the antiknock value cuts down the period that the gasoline can be kept in storage, as 5 hr. before the pressure drops off by the above test are equivalent to about 6 mos. in storage.

Several methods seem to be advocated for making vapor-lock determinations. One is by the 10-per cent-evaporated point, another by the Reid vapor-pressure at 100 deg. fahr., and a third method is by the temperature at which the Reid vapor pressure hits the 15 lb. per sq. in. absolute pressure.

In Fig. 6 are shown curves of the 10-per cent-evaporated points of two casinghead and various aviation gasolines. It will be noted how the 10-per cent points vary with respect to vapor pressure at different temperatures, and also that, of two gasolines that are identical in vapor pressure at 100 deg. fahr., one will stand a higher temperature than the other before reaching 15 lb. vapor pressure absolute.

Fig. 7 shows how propane, butane, pentane and hexane affect vapor lock. Propane develops 15 lb. vapor pressure at a temperature of about —80 deg. fahr., which clearly indicates the importance of extracting the propane from the crude oil when producing gasoline. Normal butane is somewhat better as regards vapor lock, as it reaches 15 lb. pressure at about +27 deg. fahr. Normal pentane requires a temperature of about 100 deg. to give the same pressure, and normal hexane is best, reaching this vapor pressure only at 145 deg. fahr.

Surely the petroleum industry would welcome the working out, through proper channels, of a standard specification to cover one aviation gasoline having a reasonably high antiknock value, to be used for private flying and aerial service as well as by scheduled transport consumers, and perhaps one other but not more than one additional specification to cover aviation fuel for the Army and the Navy and such scheduled transport lines and other consumers as may desire to use supercharged engines, all of whom find it necessary to go to compression ratios higher than 5.1:1 for air-cooled engines. If this can be done there is no doubt that, with the future growth of the industry, improved fuels will be developed as a natural course.

APPENDIX

Federal Specifications Board Specification No. 2d
Revised Oct. 21, 1927
Department of Commerce Technical Paper 323B

AVIATION GASOLINE, DOMESTIC GRADE

GENERAL STATEMENT

1. This specification covers the grade of gasoline used by the United States Government and its agencies for aviation fuel where the fighting grade is not required.

2. The gasoline shall be free from water and suspended matter.

PROPERTIES AND TESTS

3. *Sampling.*—Samples shall be taken according to the procedures described in Part 3 of this paper.

4. *Color.*—Method 10.11. The color shall not be darker than No. 25 Saybolt.

5. *Doctor Test.*—Method 520.3. The doctor test shall be negative.

6. *Corrosion Test.*—Method 530.1. One hundred cubic centimeters of the gasoline shall cause no gray or black corrosion and the amount of deposit, when evaporated in a polished copper dish, shall not exceed 3 mg.

7. *Distillation Range.*—Method 100.13. The temperature limits are as follows:

When 5 per cent of the sample has been recovered in the graduated receiver, the thermometer shall not read more than 75 deg. cent. (167 deg. fahr.) or less than 50 deg. cent. (122 deg. fahr.).

When 50 per cent has been recovered in the receiver, the thermometer shall not read more than 105 deg. cent. (221 deg. fahr.).

When 90 per cent has been recovered in the receiver, the

thermometer shall not read more than 155 deg. cent. (311 deg. fahr.).

When 96 per cent has been recovered in the receiver, the thermometer shall not read more than 175 deg. cent. (347 deg. fahr.).

The end point shall not be higher than 190 deg. cent. (374 deg. fahr.).

At least 96 per cent shall be recovered as distillate in the receiver from the distillation.

The distillation loss shall not exceed 2 per cent when the residue in the flask is cooled and added to the distillate in the receiver.

8. *Acidity.*—Method 510.2. The residue remaining in the flask after the distillation is completed shall not show an acid reaction.

9. *Sulphur.*—Method 520.11. Sulphur shall not exceed 0.10 per cent.

10. All tests shall be made according to the methods for testing contained in Part 2 of this paper.

11. Any military branch may require that samples be submitted for "approval tests," in addition to the laboratory tests listed above, prior to the submission of bids or award of contract. These samples shall faithfully represent those which the manufacturer intends to offer in the future under a brand name.

AVIATION GASOLINE, FIGHTING GRADE

GENERAL STATEMENT

1. This specification covers the grade of gasoline used by the United States Government and its agencies as a fuel for fighting planes, where the highest efficiency is required.

2. The gasoline shall be free from water and suspended matter.

PROPERTIES AND TESTS

3. *Sampling.*—Samples shall be taken according to the procedures described in Part 3 of this paper.

4. *Color.*—Method 10.11. The color shall not be darker than No. 25 Saybolt.

5. *Doctor Test.*—Method 520.3. The doctor test shall be negative.

6. *Corrosion Test.*—Method 530.1. One hundred cubic centimeters of the gasoline shall cause no gray or black corrosion and the amount of deposit, when evaporated in a polished copper dish, shall not exceed 3 mg.

7. *Distillation Range.*—Method 100.13. The temperature limits are as follows:

When 5 per cent of the sample has been recovered in the graduated receiver, the thermometer shall not read more than 65 deg. cent. (149 deg. fahr.) or less than 50 deg. cent. (122 deg. fahr.).

When 50 per cent has been recovered in the receiver, the thermometer shall not read more than 95 deg. cent. (203 deg. fahr.).

When 90 per cent has been recovered in the receiver, the thermometer shall not read more than 125 deg. cent. (257 deg. fahr.).

When 96 per cent has been recovered in the receiver, the thermometer shall not read more than 150 deg. cent. (302 deg. fahr.).

The end point shall not be higher than 165 deg. cent. (329 deg. fahr.).

At least 96 per cent shall be recovered as distillate in the receiver from the distillation.

The distillation loss shall not exceed 2 per cent when the residue in the flask is cooled and added to the distillate in the receiver.

8. *Acidity.*—Method 510.2. The residue remaining in the flask after the distillation is completed shall not show an acid reaction.

9. *Sulphur.*—Method 520.11. Sulphur shall not exceed 0.10 per cent.

10. All laboratory tests shall be made according to the methods for testing contained in Part 2 of this paper.

11. Any military branch may require that samples be submitted for "approval tests," in addition to the laboratory tests listed above, prior to the submission of bids or award of contract. These samples shall faithfully represent those which the manufacturer intends to offer in the future under a brand name.

Navy Department Specifications 8G1b, Sept. 1, 1917

GASOLINE

GENERAL SPECIFICATIONS

1. General Specifications for Inspection of Material, issued by the Navy Department, in effect at date of opening of bids, shall form part of these specifications.

AIRPLANE GASOLINE

QUALITY

6. To be high grade, refined, and free from water, adulterants, and impurities, and shall show a neutral reaction. No natural-gas gasoline shall be accepted nor shall they be mixed with any gasoline submitted for acceptance.

INSPECTION

7. Before acceptance the gasoline shall be inspected. Samples of each lot shall be taken at random. These samples, immeditely after drawing, shall be retained in a clean, absolutely tight closed vessel and a sample for test taken from the mixture in this vessel directly into the test vessel.

TEST

8. One hundred cubic centimeters shall be taken as a test sample.

(*a*) Boiling point shall not be higher than 120 deg. fahr.

(*b*) Fifty per cent of the sample shall distill below 221 deg. fahr.

(*c*) Eighty per cent shall distill below 275 deg. fahr.

(*d*) The end or dry point of distillation shall not be higher than 350 deg. fahr.

(*e*) Not less than 95 per cent of the liquid shall be recovered from the distillation.

GENERAL

DISTILLATION TEST

9. The apparatus and method of conducting the distillation test shall be that described in Bureau of Mines Technical Paper No. 166, Motor Gasoline.

10. The temperature at which the first drop leaves the lower end of the condenser shall be considered the initial boiling-point.

U. S. Army Specification No. 2-40-F, Dec. 14, 1926

GASOLINE, AVIATION

I. GENERAL

1. There are no general specifications applicable to this specification.

2. The current issues of the following specifications in effect on date of issuance of proposals form part of this specification:

2-22 Boxes for Oils and Greases for Export Shipment.

100-2 Standard Specifications for Marking Shipments, and Bureau of Mines Technical Paper No. 323-B, Method for Testing Lubricants and Liquid Fuels, form part of this specification.

II. GRADE

1. Gasoline shall be one grade, known as aviation grade.

III. MATERIAL

1. Only gasoline refined from crude petroleum, without the admixture of other compounds, will be considered.

2. The gasoline shall be free from water and suspended matter.

IV. GENERAL REQUIREMENTS

1. There are no general requirements applicable to this specification.

V. DETAIL REQUIREMENTS

1. *Color.*—Method 10.11. The color shall not be darker than No. 25 Saybolt.
2. *Doctor Test.*—Method 520.3. Doctor test shall be negative.
3. *Corrosion Test.*—Method 530.1. One hundred cubic centimeters of the gasoline evaporated in a polished copper dish shall cause no gray or black corrosion, and the amount of deposit shall not exceed 3 mg.
4. *Acidity.*—Method 510.2. The residue remaining in the flask after the distillation is completed shall not show an acid reaction.
5. *Sulphur.*—Method 520.1. Sulphur shall not be over 0.10 per cent.
6. *Critical Temperature of Solution.*—Method outlined in Section VI, 4, of this specification. The critical temperature of solution with aniline, after nitration, shall not exceed 62.0 deg. cent.
7. *Distillation Range.*—Method 100.12. The temperature limits are as follows:

(*a*) When 5 per cent of the sample has been recovered in the graduated receiver the thermometer shall not read more than 75 deg. cent. (167 deg. fahr.). or less than 50 deg. cent. (122 deg. fahr.).
(*b*) When 50 per cent has been recovered in the receiver the thermometer shall not read more than 105 deg. cent. (221 deg. fahr.).
(*c*) When 90 per cent has been recovered in the receiver the thermometer shall not read more than 155 deg. cent. (311 deg. fahr.).
(*d*) When 96 per cent has been recovered in the receiver the thermometer shall not read more than 175 deg. cent. (347 deg. fahr.).
(*e*) The end point shall not be higher than 190 deg. cent. (374 deg. fahr.).
(*f*) At least 96 per cent shall be recovered as distillate in the receiver from the distillation.
(*g*) The distillation loss shall not exceed 2 per cent when the residue in the flask is cooled and added to the distillate in the receiver.

VI. METHODS OF INSPECTION, TESTS, ETC.

1. The gasoline shall be subject to inspection by authorized Government inspectors who shall be given all necessary facilities to determine compliance with this specification.
2. Acceptance or approval of material in course of manufacture shall in no case be construed as a guaranty of the acceptance of the finished product.
3. All tests shall be made in accordance with "Methods for Testing Lubricants and Liquid Fuels," contained in Technical Paper No. 323-B, Bureau of Mines.
4. Method for determining the critical temperature of solution. Two hundred cubic centimeters of gasoline are nitrated with 50-cc. portions of a mixture of three parts H_2SO_4 (specific gravity 1.84) and one part HNO_3 (specific gravity 1.41) until no more heat is developed. (Plunge into ice water if mixture becomes hot to the hands.) Wash with concentrated H_2SO_4 until free from nitro compounds, then once with distilled H_2O, then thoroughly with 20 per cent caustic-soda solution, followed by distilled H_2O until all caustic is removed. Dry the resultant gasoline over anhydrous $CaCl_2$ and determine the critical temperature of solution as follows: Place 5 cc. of chemically pure redistilled aniline in a tube the same as the one in the A.S.T.M. paraffin wax melting-point apparatus (Serial D-87-22) and add 0.5 cc. of the gasoline nitrated as above. Close the tube which includes the thermometer and stirrer and immerse in water at a temperature above which complete solution will occur. Allow the water, tube, and contents to cool slowly with stirring and note the temperature at which decided turbidity occurs. Repeat this process with 0.5-cc. additions of gasoline until the solution temperature reaches a maximum. This maximum temperature is the critical temperature of solution of the nitrated gasoline.

Engine Manufacturer's Specification

U. S. GOVERNMENT SPECIFICATION FOR AVIATION GASOLINE, DOMESTIC GRADE B, EXCEPT BLENDED WITH ETHYL FLUID

1. This specification covers the grade of gasoline used by the United States Government and its agencies for aviation fuel where the Fighting Grade is not required.
2. The gasoline shall be free from water and suspended matter.

PROPERTIES AND TESTS

3. *Color.*—Method 10.11. The color shall not be darker than No. 25 Saybolt.
4. *Doctor Test.* Method 520.3. The doctor test shall be negative.
5. *Corrosion Test.*—Method 530.1. One hundred cubic centimeters of the gasoline shall cause no gray or black corrosion and the amount of deposit when evaporated in a polished copper dish shall not exceed 3 mg.
6. *Distillation Range.*—Method 100.12. The temperature limits are as follows:

When 5 per cent of the sample has been recovered in the graduated receiver, the thermometer shall not read more than 75 deg. cent. (167 deg. fahr.) or less than 50 deg. cent. (122 deg. fahr.).

When 50 per cent has been recovered in the receiver, the thermometer shall not read more than 105 deg. cent. (221 deg. fahr.).

When 90 per cent has been recovered in the receiver, the thermometer shall not read more than 155 deg. cent. (311 deg. fahr.).

When 96 per cent has been recovered in the receiver, the thermometer shall not read more than 175 deg. cent. (347 deg. fahr.).

The end point shall not be higher than 190 deg. cent. (374 deg. fahr.).

At least 96 per cent shall be recovered as distillate in the receiver from the distillation.

The distillation loss shall not exceed 2 per cent when the residue in the flask is cooled and added to the distillate in the receiver.

7. *Acidity.*—Method 510.2. The residue remaining in the flask after the distillation is completed shall not show an acid reaction.
8. *Sulphur.*—Method 520.1. Sulphur shall not be over 0.10 per cent.
9. All tests shall be made according to the methods for testing contained in U. S. Navy Specifications 7G-1B and U. S. Air Service Specification 2-40.
10. All gasoline furnished under this specification must have a specific gravity of 0.71 minimum. Baumé gravity range of 66-68. It is desired, however, that the gasoline be as high in antiknock value as is possible, consistent with the other requirements of this specification.
11. All gasoline furnished under this specification must be thoroughly mixed with sufficient Ethyl fluid to provide 2 cc. of tetraethyl lead per gallon of gasoline.

It is understood that the addition of Ethyl fluid will change the color and quality of the fuel, therefore the portion of this specification relating to the distillation and test of the fuel must of necessity apply to the gasoline before mixing.

Navy Department Specification 7G1c, June 1, 1928

GASOLINE

Technical requiremens conform in detail to United States Master Specification No. 2d, revised by the Federal Specifications Board on Oct. 21, 1927. Copies of United States Government Master Specifications are unnecessary for bidders and are not available for distribution by the Navy Department.

GENERAL SPECIFICATIONS

1. General specifications for Inspection of Material, together with Appendix VI (Lubricants and Liquid Fuels), issued by the Navy Department, in effect at date of opening of bids, shall form part of these specifications.

GRADE

2. Gasoline shall be furnished as required, in three grades, as follows:

Grade A—Gasoline, fighting aviation
Grade B—Gasoline, domestic aviation
Grade C—Gasoline, motor

(b) *Grade B, Domestic Aviation Gasoline.*—Shall conform to the following requirements:

(1) The gasoline shall be free from water and suspended matter.

(2) *Color.*—The color shall not be darker than No. 25 Saybolt.

(3) *Doctor Test.*—The doctor test shall be negative.

(4) *Corrosion Test.*—One hundred cubic centimeters of the gasoline shall cause no gray or black corrosion and the amount of deposit, when evaporated in a polished copper dish, shall not exceed 3 mg.

(5) *Distillation Range.*—The temperature limits are as follows:

When 5 per cent of the sample has been recovered in the graduated receiver, the thermometer shall not read more than 75 deg. cent. (167 deg. fahr.) or less than 50 deg. cent. (122 deg. fahr.).

When 50 per cent has been recovered in the receiver the thermometer shall not read more than 105 deg. cent. (221 deg. fahr.).

When 90 per cent has been recovered in the receiver, the thermometer shall not read more than 155 deg. cent. (311 deg. fahr.).

When 96 per cent has been recovered in the receiver, the thermometer shall not read more than 175 deg. cent. (347 deg. fahr.).

The end point shall not be higher than 190 deg. cent. (374 deg. fahr.).

At least 96 per cent shall be recovered as distillate in the receiver from the distillation.

The distillation loss shall not exceed 2 per cent when the residue in the flask is cooled and added to the distillate in the receiver.

(6) *Acidity.*—The residue remaining in the flask after the distillation is completed shall not show an acid reaction.

(7) *Sulphur* shall not be over 0.10 per cent.

(e) The right is reserved to reject any bids on brands of Grade A and Grade B gasoline which have not been subjected to the required tests and found satisfactory.

Must exceed antiknock rating as tested with N.A.C.A. Engine with 5.8:1 compression ratio.

Knock Values *of* Aviation Fuels

By Edwin E. Aldrin[1]

THE paper is an effort to provide a common basis for determining the relative knock-values of various aviation fuels. With this object in mind the author presents a chart showing data based on laboratory and flight tests of aviation engines with various fuels.

The author points out that, generally speaking, the better the knock rating the lower the cylinder temperature. Until more experimental evidence has been obtained, he considers that vapor pressure is of secondary importance in its relation to vapor lock.

RELATIVE knock-values of various aviation fuels have been the subject of considerable debate. The difficulty lies largely in not having a common language and uniform conditions for test. Much progress is being made in rectifying this by various committees working with or associated with the Society of Automotive Engineers and the petroleum industry represented largely by the American Society for Testing Materials. Testing of various aviation engines in the laboratory and in flight on different kinds of fuel has given certain data that I am attempting to depict in graphic form. Fig. 1 represents my own personal system of clarifying the information I had accumulated up to a few weeks ago. In other words, I am trying to put my experience on the chart.

To those who have studied the subject the practical impossibility of comparing the effect of fuels in water-cooled and air-cooled engines, whether they be full-scale or fuel-testing engines, is obvious. In fact, we have compared our results with those obtained by many other testing laboratories and found that some of the fuels give very different values when tested at 300 deg. instead of 210 in the Ethyl Gasoline knock-testing engine just as in air-cooled and water-cooled engines in flight. Specialists on knock testing will certainly be able to point out many faults in the chart that I am presenting, merely because we have to be practical in talking about the knock values of fuels. The accuracy is sufficient to make rough and ready determinations of the safe fuel for the classes of engine represented. It is presented with the idea of starting discussion and others possibly will do something better the next time. In fact, I can criticize it very severely myself, but I have not yet hit upon a better method of presenting the available facts and would appreciate constructive criticism in this connection. I shall outline some of my own criticisms of this tabulation and then ask for questions from the audience to guide me in explaining some of the details that might not be clear.

This chart represents the worst knock rating at the top and better knock rating as we go down the scale. I would not want to guarantee that the results are particularly close, but the order of merit runs about as shown. To begin with, the Standard Oil of New Jersey scale is based upon standards of fuel. We have a standard that we call 10 knock rating when tested in the Ethyl Gasoline engine at 210 deg., and we have a substandard at 5, and we can obtain zero by mixing 50 per cent of benzol in the 10 knock-rating gasoline. The scale is just extended for the purpose of reference.

[1] M.S.A.E.—Manager of aviation department, Standard Oil Co. of New Jersey, New York City.

The Navy test on the National Advisory Committee for Aeronautics variable-compression engine giving a 5.65 highest useful compression ratio corresponds pretty closely to 5. The other test of a 5.80 highest useful compression ratio comes down fairly close to 3, and the 6.15 highest useful compression ratio comes pretty close to an Ethyl Aviation Standard that was tentatively set for the Ethyl Gasoline Corp. some time ago for reference purposes.

The interpretation of the chart would be that we would not want to fly the Cyclone engine on fuel which is in that upper part of the category unless we intended to run it throttled at all times with the mixture control full rich. The same applies to water-cooled engines. I believe the rest is pretty easy to understand. With Mid-Continent Motor fuel, sometimes we will have as bad a knock rating as 12, sometimes even better than 10. These fuels are typical ones that we picked up. At 5 we may group some other different types of gasoline; certain West Texas gasolines also fall in that category. The distillation of a particular gasoline affects its knock value considerably. We called them Domestic Aviation Grade, but it is rather hard to get them falling pretty close to 374 end-point.

Straight-run fuels are fairly accurately represented. The benzol values shown are for 210 deg. or water-cooled engines; for 300 or higher cylinder temperatures its effect is reduced. Cracked fuels generally fall to a considerably inferior position when tested at 300 instead of 210 deg. Better antiknock fuels, with a knock rating of 5 or less, may not be worthy of a position so comparatively favorable as was found for them on the water-cooled test-engine, when they are tested on full-scale air-cooled engines which would come between those shown on the chart, especially if they are cracked or contain benzol. No exact marks are made on the scale because of this reason and also of the experimental error. In testing fuels at 300 deg., we find all the "bad blood" greatly exaggerated in spite of dopes that are added. In other words, as cylinder temperatures are increased, the effect of dope added to a poor-base gasoline is less and less. Whatever the defects of the chart, our experience has been that fuels equal or better in knock rating than those indicated will be safe under the worst conditions. I have avoided the question of relative cylinder-heat temperatures in the various full-scale aircraft engines. The criterion for the full-scale air-cooled engines has been excessive cylinder-head temperatures. In the full-scale water-cooled engines the criterion has been largely drop of power and audible knock. In the Navy variable-test engine the audible method has been used. In the Standard Oil Co. of New Jersey scale-test engine the Midgley bouncing-pin has been used.

The importance of knock value in aviation engines cannot be overestimated. The better the knock value, generally speaking, the lower the cylinder temperature, and therefore better lubrication can be maintained, with a net result that the engines will last longer between overhauls, will allow of reasonable oil-consumption and possess a multitude of other related advantages. Such questions as have been up for discussion previously, such as the vapor pressure of the fuel, which have an

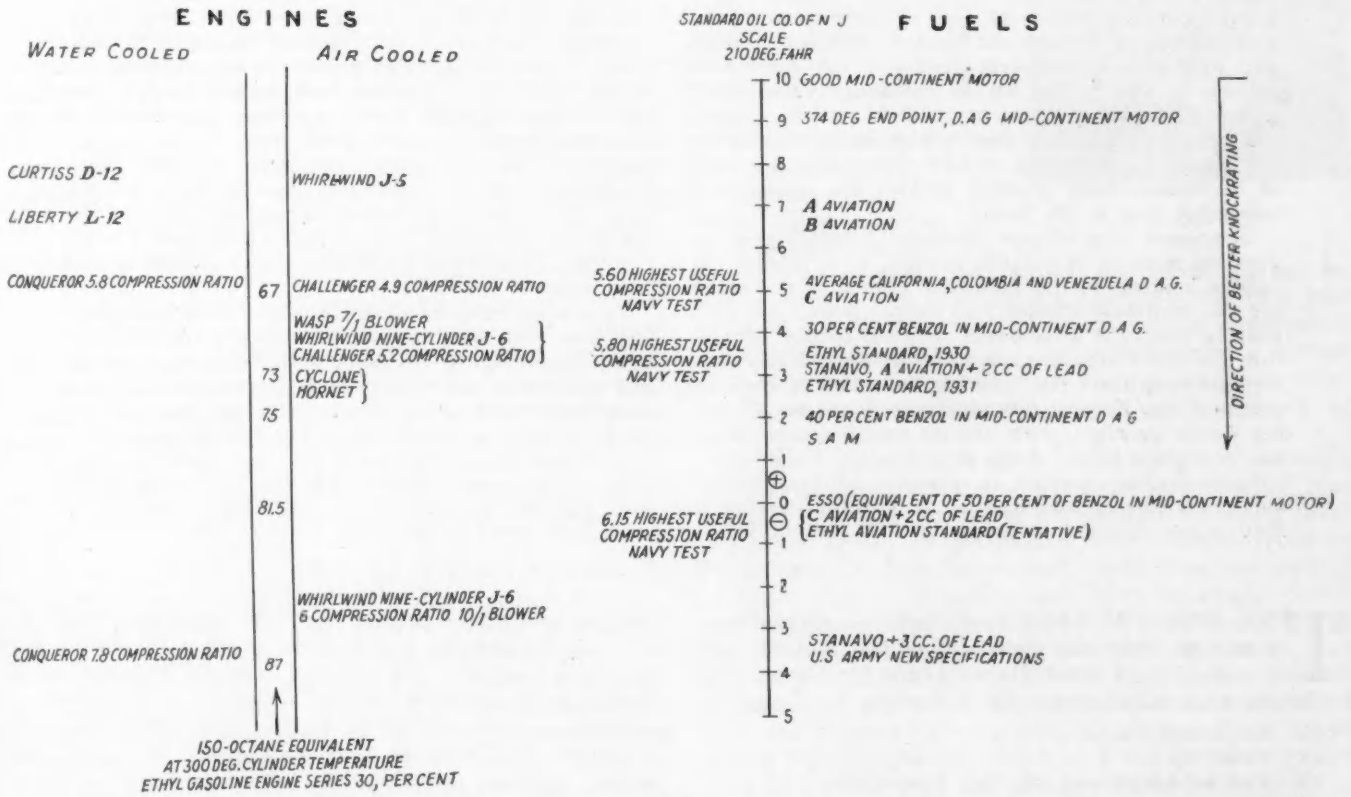


FIG. 1—POOREST PERMISSIBLE KNOCK-RATING FOR AVIATION ENGINES AT FULL THROTTLE AND UNDER ADVERSE OPERATING-CONDITIONS

In This Chart Esso, Which Is the Equivalent of a 50 Per Cent Blend of Benzol and Mid-Continent Gasoline, Is Taken as Zero and the Various Fuels Are Arranged in the Order of Their Knock Values Based on This Scale. The Engines Are Placed Approximately Opposite the Fuel Having the Lowest Knock-Rating on Which They Will Operate at Full Throttle under Adverse Conditions

indirect bearing on knock rating, have not been considered at this time because I believe that, until more practical experimental evidence has been obtained, vapor pressure is of secondary importance and sometimes greatly exaggerated in its relative effect on vapor-lock qualities.

Fuel Requirements *of the* Gasoline Aircraft-Engine

By S. D. Heron[1]

FUELS for use in aircraft engines are discussed with reference to their antiknock value, volatility, vapor-locking and engine-starting properties, gum content and availability, and to antiknock agents.

The usefulness of a fuel for spark-ignition engines is stated to be limited by its tendency to heat the cylinder and the piston unit. Definite evidence is available that the tendency of fuels to heat the cylinder unit is not always in accord with their tendency to cause audible knocking.

The fuel required depends upon the compression ratio of the engine, its volumetric efficiency, the design, size and temperature of the cylinder unit, and the rate of revolution. Mid-Continent Domestic Aviation gasoline having an approximate antiknock value of 50 octane-50 heptane gives excellent results if the engine output is kept within the limitations of this fuel but is not suitable for many modern aircraft engines if flown wide open at sea level. Fuel having an antiknock value of 70 to 75 octane, 30 to 25 heptane is amply good for most modern commercial and military airplanes, except certain fuels that lose antiknock value excessively at high cylinder-temperature. For engines of the ground-boosted, high-compression and high-cylinder-temperature types, the Air Corps intends to standardize on an antiknock value of 87 octane 13 heptane.

Engine performance that is now being secured by the Materiel Division of the Air Corps does not seem to be commercially possible without the addition of tetraethyl lead to the fuel.

In present type engines Domestic Aviation gasoline does not seem to be volatile enough, as somewhat excessive heating of the induction system is necessary for the minimum specific fuel consumption, and such heating results in a reduction of power output. Therefore the Air Corps has adopted for use in super-performance engines a fuel meeting the volatility requirements of the Federal Specifications Board for Fighting Grade gasoline, with certain modifications called for by United States Army Specification Y-3557-A.

Vapor-locking trouble in present military equipment is violently accentuated by gasoline having a Reid vapor pressure in excess of 7 lb. per sq. in. at 100 deg. fahr. Therefore, pending development of improved fuel systems, Specification Y-3557-A fixes an upper limit of 167 deg. fahr. on the 10-per cent-evaporated point and a maximum Reid vapor pressure of 6½ lb. at 100 deg. fahr. The Air Corps, however, is working to improve fuel systems, which it believes should embody pressure feed of the fuel by a pump the suction of which is below the lowest point of the fuel tanks, which is not subjected to heat and which has a capacity greatly in excess of the maximum engine-demand. It plans a system that will avoid pump vapor-locking with fuel having a vapor pressure of 16 to 17 lb. per sq. in. at 100 deg. fahr.

Little reason seems to exist at present for excluding cracked gasoline for aviation use. Endurance tests in flight have shown no undesirable effects from gum in such gasolines containing less than 10 mg. per 100 cc.

Ample supplies of Fighting Grade gasoline having an antiknock value of 70-75 octane 25-30 heptane, of both gum-stable cracked and straight-run types, seem to be available. Apparently the best method of increasing the antiknock value is the addition of tetraethyl lead and aromatics. Benzol seems to be relatively ineffective at high cylinder-temperatures and causes ice formation in the fuel system if more than 20 per cent is added to the gasoline. Aromatics of low freezing-point, synthesized from benzol, apparently are the only other generally available antiknocks suitable for sufficiently raising the antiknock value. The Air Corps feels that troubles arising from the use of tetraethyl lead in aircraft engines can be overcome by changes in engine design, material and lubrication.

Very large supplies of straight-run California gasoline that will meet the antiknock value required by Army Specification Y-3557-A with less than 6 cc. of lead per gallon are available; and straight-run gasolines from other crudes that will meet the requirements seem to be obtainable in considerable quantity. Some cracked gasolines without lead additions are found to be superior to straight-run California gasolines without lead additions, but their response to added lead seems to be slight.

THE REQUIREMENTS of fuel for aircraft-engine use, from the viewpoint of the Materiel Division of the United States Army Air Corps, may be briefly considered under the following headings:

(1) Antiknock Value
(2) Volatility
(3) Vapor-Locking and Starting Properties
(4) Gum
(5) Available Fuels and Antiknocks

There is little question that the tendency to heat the cylinder and piston unit is the most important property of a fuel for use in a spark-ignition aircraft engine, and it is this property that sets a limit to its usefulness. Fuel that is deficient in the property of suppressing overheating for any given engine will result in rapid failure of the cylinder unit as a result of stuck and melted pistons, overheated and burnt-out exhaust valves, and spark-plug overheating, which at times results in melted insulators.

Whether the tendency of a fuel to heat the cylinder unit is due to detonation, its tendency to preignition or an effect related to both detonation and preignition is

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not known. There is definite evidence, however, that the relative tendencies of fuels to heat the cylinder unit are not always in accord with their tendencies to produce audible knock. Very largely saturated gasolines containing tetraethyl lead, when tested against similar gasolines blended with aromatics, at times show pronounced differences in audible knock for equal cylinder-temperature. Comparison of the quality of knock when testing such blends is difficult, as the lead blend will produce a sharp ping, whereas the aromatic blend produces a sound more like a thud. In extreme cases of testing very diverse types of fuel at equal cylinder-temperature, the lead blend produces a sharp knock and the aromatic blend only the slightest thud. This is notably true when testing a highly naphthenic gasoline with 3 to 6 cc. of lead added against an *n*-heptane-benzol blend at high cylinder-temperature.

In the following discussion of fuel usefulness, which is for the present defined as antiknock value, the values referred to are determined on the Series-30 Ethyl Gasoline Corp. knock-test engine at 300 deg. fahr. jacket-temperature and 600 r.p.m. as specified in United States Army Specification Y-3557-A. As later discussion will show, it is realized that the relative ratings thus obtained are not in accord with results obtained in multicylinder aircraft engines with high cylinder-wall temperature.

Engine Factors That Affect Fuel Requirements

The fuel required by an aircraft engine depends upon the compression ratio; the volumetric efficiency, including the degree of supercharge; the design, size and temperature of the cylinder unit; the rate of revolution, and the mixture temperature at the intake valves.

Until recently, Mid-Continent Domestic Aviation gasoline having an approximate antiknock value of 50 octane (2-2-4 trimethyl pentane) 50 heptane, has been the most generally used American aircraft-engine fuel. It gives excellent results if the engine output is kept within the limitations of this fuel, but it is not suitable for many modern military or commercial engines if they are flown wide open at sea level. Mid-Continent D.A.G. is inferior in antiknock value to much of the low-test automobile gasoline on the market.

For most modern commercial and military engines, with the exception of high-compression and ground-boosted types, fuel having an approximate antiknock value of 70-75 octane, 30-25 heptane is amply good enough, with certain reservations as to fuels which show excessive loss of antiknock value at high cylinder-temperature. This antiknock value is roughly that of premium automobile gasolines of the cracked and doped types when these are tested at low cylinder-temperature.

For high-performance engines of the ground-boosted high-compression and high-cylinder-temperature types, the Air Corps has the present intention of standardizing an antiknock value of 87 octane 13 heptane.

The relative antiknock values of fuels for aircraft purposes appear to vary widely with test-engine conditions, at least when tested by the method of working at partial throttle and a pronounced knock. The most pronounced change in relative value is produced by variation of cylinder temperature, particularly when comparing lead and benzol in highly naphthenic California gasolines. In measuring detonation by the tendency to heat the cylinder unit (if the effect measured is detonation), the Materiel Division has found that the amount of tetraethyl lead required to equal 50 per cent benzol in a California Fighting Grade gasoline varies by several hundred per cent between the limits of 200 and 400 deg. fahr. cooling-liquid temperature, the lead requirement rapidly dropping with increasing jacket temperature. Similar tests of lead and benzol in an average Mid-Continent D.A.G. showed that, between the limits of 150 and 400 deg. fahr. jacket-temperature, the lead equivalent of 50 per cent benzol varied by over 100 per cent. Using a similar California gasoline, the same Mid-Continent D.A.G. and benzol, the same engine equipment, and measuring detonation by both temperature and bouncing-pin methods, the Ethyl Gasoline Corp. and the Standard Oil Development Co. have found that, at 350 deg. fahr. jacket-temperature, the lead equivalent of 50 per cent benzol is subject to more than 100 per cent variation, both as a result of change of rate of test-engine revolution and of knock intensity.

Temperature Method of Rating May Be Preferable

The problem of rating aircraft-engine fuels in terms of their usefulness in multicylinder engines is, owing to the importance of the cylinder-heating effect, probably distinctly different from that of rating automobile fuels. In the case of automobile fuels, rating by audible knock with a jacket temperature of 212 deg. fahr. seems to give results that coordinate closely with road-test results. It is suspected, however, from consideration of the fuel requirements of racing cars having very high compression or a high degree of supercharging, that test-engine ratings of diverse types of fuel by audible knock at 212 deg. fahr. jacket-temperature would not be in agreement with results in the cars, as the heating effect of a fuel for such use appears to be of pronounced importance.

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There is reason to believe that a temperature method of rating fuels for aircraft use may prove to be more desirable than one depending upon audible knock or rate of pressure rise.

In this connection, some evidence obtained in multicylinder aircraft engines suggests that tetraethyl lead has an effect in suppressing overheating of the cylinder unit that is out of proportion with its properties of suppressing audible knock and controlling the rate of pressure rise. Tetraethyl lead in quite small concentrations has a remarkable effect in suppressing preignition and autoignition. This possibly suggests, in view of the pronounced effects of lead in allowing increase of output in engines of high cylinder-wall temperature, that the tendency to preignition is one of the major causes limiting the usefulness of a fuel in such engines.

It is possible that the effects of lead in suppressing cylinder heating and preignition (which may be one and the same effect) in engines with high cylinder-temperature may be due to the dispersed particles of lead compounds functioning as a screen against the transmission of radiant heat from the charge to the com-

bustion-chamber walls during the period of maximum flame-temperature. It is believed that, during the early part of the work of Kettering, Midgley and Boyd on antiknock compounds, it was considered that one method by which an antiknock might function was as a screen to radiant-heat energy.

Tetraethyl Lead Essential to High Performance

In the light of present knowledge, engine performance now being secured by the Materiel Division of the Air Corps would not appear to be commercially possible without the use of fuels containing tetraethyl lead. Some very recent tests on a Curtiss V-1150 engine with 7.3:1 compression-ratio, operating at 300 deg. fahr. jacket-outlet temperature and 2300 r.p.m., have consistently shown a brake mean effective pressure of 143 lb. per sq. in. at a specific fuel consumption of 0.41 lb. per hp-hr.; this with the mixture leaned out so as to drop the power 1 per cent from the maximum ("best setting"). The fuel used was a California Fighting Grade gasoline containing 7 cc. of lead per gal. The antiknock value of the undoped gasoline is 69 octane 31 heptane, and 90 octane 10 heptane when doped with 7 cc. of lead. Using 20 per cent of this gasoline and 80 per cent of motor benzol having a minimum freezing-point of 24 deg. fahr. (approximately 20 per cent toluene content), the engine developed the same power as on the lead blend but with a specific fuel consumption of 0.44 lb. at "best setting." With 50 per cent of the gasoline mentioned, 50 per cent motor benzol and 3½ cc. of lead in the mixture, 143 lb. brake mean effective pressure and 0.44 lb. specific fuel consumption at "best setting" was obtained. In all these tests, slight after-firing was observed on cutting the ignition switch, and the running was noticeably smoother on the blend of gasoline with 7 cc. of lead than it was with the gasoline-benzol blend or the gasoline-benzol-lead blend.

In a previous series of tests, this same engine consistently gave 143 lb. brake mean effective pressure with 0.41 lb. specific fuel consumption at "best setting," using the same California gasoline with 6 cc. of lead, a clean cut on the ignition switch being obtained, colder spark-plugs being used than with the gasoline plus 7 cc. of lead, gasoline plus 80 per cent of benzol and gasoline plus 50 per cent of benzol plus 3½ cc. of lead. With the California gasoline and 50 per cent of benzol, the output was less than 143 lb. brake mean effective pressure and prolonged after-firing was evident on cutting the ignition switch. With 60, 70 and 80 per cent of benzol, 143 lb. brake mean effective pressure was obtained at a specific fuel consumption of 0.54 lb. Attempts to lean the mixture from this consumption resulted in sharp drop of power. Pronounced after-firing with all these blends was evident on cutting the ignition switch. The high fuel consumption in the last-mentioned test with the 80-per cent benzol blend was due to exhaust-value condition resulting from overheating when running on the 50, 60 and 70-per cent benzol blends.

The foregoing discussion serves to indicate that the problem of the measurement, in fuel-test engines, of the usefulness of diverse fuels in multicylinder aircraft engines is exceedingly complex. For its solution, it would appear that a variety of types of multicylinder engine must be tested with a variety of base fuels, the amount of antiknock material necessary in each fuel for optimum performance being determined. Fuel-test-engine conditions, and possibly test-engine type, must then be obtained which on the average match the average results obtained in multicylinder engines.

While anything like a complete knowledge of the relative behavior of different fuels in multicylinder aircraft engines and fuel-test engines is probably several years off, a test which provides partial control of antiknock value is preferable to no test at all. Therefore, the Air Corps, in its recently issued tentative Specification Y-3557-A for Fighting Grade Antiknock gasoline, specified test conditions in accordance with its best judgment of the problem at the time of issue, conditions being set so as not to bear unduly on cracked or aromatic blends.

At the time of issue it was suspected that the test conditions would not reproduce multicylinder-engine results as regards cracked gasolines and aromatic blends with and without lead added, in comparison with highly naphthenic gasolines with or without lead added. Recent multicylinder-engine test results have confirmed the suspicions that the test conditions specified in Specification Y-3557-A are not severe enough upon undoped aromatic blends; for example, the test results quoted for the 7.3:1 compression-ratio Curtiss V-1150 engine with 300 deg. fahr. jacket-temperature. Furthermore, in multicylinder engines with high cylinder-wall temperature and high compression, or highly supercharged water-cooled engines, California gasoline having a lead content of 6 cc. has several times been shown to be superior to the same gasoline-lead blend with benzol added in quantities of 30 per cent, thus reducing the lead concentration. It has been proved possible to match the results obtained from the super-performance multicylinder engines by modifying the test conditions specified in Specification Y-3557-A to increase the jacket temperature from 300 deg. fahr. to 350 deg. fahr. and the engine speed from 600 to 900 r.p.m. and to measure the fuel value by a temperature method rather than by the bouncing pin.

Difficulties of Testing at High Temperatures

Incidentally, the experience of the Materiel Division is that fuel testing at high cylinder-temperatures is as yet by no means an easy procedure, for the following reasons:

(1) Any suitable liquid for high-temperature cooling is extremely difficult to exclude from the combustion-chamber if a detachable cylinder-head with liquid passing the gasket be used. The slightest leak causes rising and falling knock and precludes any accurate testing. This difficulty with leakage of high-temperature cooling media is not by any means confined to fuel-test engines.

(2) The slightest amount of oil-pumping produces effects similar to (1).

(3) The results seem to be affected much more by slight changes of air-to-fuel ratio than they do by addition of antiknock compound to a given fuel. Therefore a relatively insensitive carbureter that not merely maintains the same air-to-fuel ratio from cycle to cycle over a short period but also maintains a practically constant average mixture-ratio over extended periods of running, is necessary.

In this connection, the Ethyl Gasoline Corp. has found that, at 212 deg. fahr. jacket-temperature, aviation gasolines are a great deal more sensitive to change of carbureter float-level than are motor gasolines. Using a similar test engine, the Materiel Division has found

that, at 300 deg. fahr. jacket-temperature and otherwise similar test-conditions, California Fighting Grade gasoline with and without lead addition is, roughly, four times as sensitive to change of carbureter float-level as is Ethyl Gasoline Motor Standard Reference Fuel. The California Fighting Grade gasolines are the most sensitive fuels to float level or mixture ratio yet tested by the Materiel Division. This sensitivity to float level in the case of the Series-30 Ethyl Gasoline Corp. knock-test engine is, in the experience of the Materiel Division, roughly reduced to one-fourth by increase of rate of engine revolution from 600 to 900 r.p.m. at jacket temperatures of 300 and 350 deg. fahr.

(4) At low test-engine speeds, the engine takes an excessive time to reach stability when switching from one fuel to another. This apparently is due to the relatively low rate of heat flux to the cylinder-walls. Further, when testing fuels that have varying tendencies to heat the cylinder but which are matched by the bouncing pin and audible knock, the cylinder temperature has to change before stable conditions are reached each time the engine is switched from one fuel to another.

Volatility

For minimum fuel consumption without excessive heating of the induction system and consequent power loss, D.A.G. does not appear to be volatile enough for most present types of engine. Therefore the Air Corps has, in Specification Y-3557-A, which is for use in superperformance engines, adopted Federal Fighting Grade volatility requirements with modifications which are discussed under the head of Vapor Locking and Starting Properties.

Fuel-injection devices now undergoing test and injecting either into the combustion-chamber or the induction system may allow the use of less volatile fuel than D.A.G. without power drop or distribution troubles.

Vapor-Locking and Starting Properties

Vapor locking is an intermittent trouble with present Air Corps equipment, and gasoline having a Reid vapor pressure of over 7 lb. per sq. in. at 100 deg. fahr. violently accentuates the trouble. Air Corps fuel-systems were developed around fuel having a Reid vapor pressure of 4 to 6 lb. at 100 deg. fahr. and a lower limit of 150 deg. fahr. on the 10-per cent-evaporated point. Army Specification Y-3557-A has, therefore, specified an upper limit of 167 deg. fahr. on the 10-per-cent-evaporated point and a maximum Reid vapor pressure of 6½ lb. at 100 deg. fahr. This is pending the development of improved fuel-systems.

A recent case of general vapor-lock trouble with a whole squadron of airplanes of mixed type was traced to the use of a gasoline having 7.4 lb. Reid vapor pressure and a 10-per cent-evaporated point of 137 deg. fahr., high atmospheric temperature being a contributing cause.

The most general type of fuel system in use in the Air Corps is decidedly bad as regards tendency to vapor-lock. The fuel pump generally has a suction lift, in some cases up to 5 ft., is surrounded by air directly heated by the engine and, worse still, is bolted to some portion of the rear end of the engine, thus being subjected to direct heat-transmission from the engine. Thus it is not surprising that vapor-locking on the suction side of the fuel pump is by no means unknown. All vapor-lock troubles experienced by the Air Corps to date have been confined to the delivery of fuel to the carbureter.

Vapor lock in the fuel lines leading from the tanks to the curbureter is experienced at times with gravity systems. Fuel-boiling in the carbureter float-bowls and in the jets is, as far as the experience of the Air Corps goes, not of consequence with present engines and gasoline having a Reid vapor pressure of 9 lb. or less. With highly supercharged airplanes capable of altitudes in excess of 30,000 ft., the deficiencies of the usual type of Air Corps fuel-system referred to became apparent several years ago, and pumps driven by flexible shafts and avoiding suction lift were resorted to with success as regards vapor lock. It would seem that the reduction of temperature of the pump unit as a result of removing it from the engine may have been quite as much responsible for the elimination of vapor lock with this type of pump as was the avoidance of suction lift. Unfortunately, the flexible-shaft drives used were of crude type and served to foster belief in the general unreliability of such drives.

Features of an Ideal Fuel System

The Air Corps, in the light of present knowledge, believes that the ideal fuel-system would embody the following features:

(1) Pressure feed by a pump rather than of the gravity type

Modern carbureters function considerably more uniformly with a constant fuel-pressure of approximately 3 lb. per sq. in. than they do when fed by gravity. This is particularly the case in bumpy weather or when maneuvering violently.

(2) Pump suction below the lowest point of any of the fuel tanks

This may not be possible if dropable tanks be used.

(3) Pump not directly attached to the engine, thus avoiding direct heat-transmission, and, if possible, placed to the rear of the fire wall and out of the air directly heated by the engine

Every effort should be made to cool the pump unit and the gasoline passing through it. This can possibly be done in many cases by making a pump of streamline shape and projecting it beyond the lower portion of the fuselage.

(4) Pump capacity greatly in excess of the maximum engine-demand

This, with such alteration of present-type fuel circuits that the gasoline in excess of the engine demand is bypassed back to the tanks instead of to the suction side of the pump and the provision of cooling either on the pump or in some sort of radiator, will render possible the securing of a greater temperature drop of the gasoline with increasing altitude than now occurs. Bypassing the fuel back to the tanks rather than to the suction side of the pump may, however, result in altogether undesirable complications. Furthermore, such bypassing will, with the provision of a gasoline cooler, affect the temperature of the fuel only in the tank that happens to be in use. The work of Bridgeman, Aldrich and White[2], at the Bureau of Standards has

[2] See Vapor-Pressure Data on Motor Gasolines, S.A.E. JOURNAL, May, 1929, p. 488; Properties of Gasolines with Reference to Vapor Lock, S.A.E. JOURNAL, July, 1930, p. 93; and Vapor-Locking Tendencies of Aviation Gasolines, S.A.E. JOURNAL, August, 1930, p. 218.

shown the importance of reducing the temperature of the fuel as the atmospheric pressure drops with altitude. Drastic cooling of the gasoline with increasing altitude has, however, a hazard from the freezing of dissolved and other water present in the fuel and in the tanks. Freezing of fuel-strainer traps at altitudes of the order of 20,000 ft. is experienced at times with present-type fuel-systems.

System for Higher-Vapor-Pressure Fuels

The Air Corps realizes that a Reid vapor pressure of 6½ lb. per sq. in. is not compatible with its demands for increasing antiknock value and also that, with present fuel systems, 6½ lb. Reid vapor pressure does not provide an adequate margin of safety, if any, under exceptional atmospheric conditions. Active steps in the improvement of fuel systems are, therefore, being undertaken.

Preliminary experiments have indicated promise in a hydraulic drive for fuel pumps. This consists of a special pump on the engine which draws liquid from an expansion tank and feeds a hydraulic motor which, in turn, drives the fuel pump. The liquid used in the system will be of low freezing-point and may be an oil or a mixture of water, methanol or ethyl alcohol with glycerine, glycol or a glycol derivative. Electric drives of either direct or alternating-current type for fuel pumps are also under consideration, and work is being done on flexible-shaft drives. While the drives of this type used in the past by the Air Corps have been crude, their performances in supercharged airplanes have not been too unreliable and, despite occasional mechanical failure, the net reliability of the fuel systems equipped with pumps thus driven has proved to be far better at extreme altitudes than systems with the mechanically reliable direct-drive pump which is subject to vapor lock.

In case of failure of the fuel system to operate, either as a result of breakage of the flexible shaft or vapor-locking of the direct-drive pump, the remedy to secure continued operation of the engine is the same in both cases; namely, use of the hand pump. For a start, the obvious crudities of high local-stress concentrations in the flexible-shaft drive are being eliminated. Hydraulic and electric drives for fuel pumps render possible a flexibility of installation that is not obtainable with flexible-shaft drives. The latter, however, are simpler and thus at least worthy of study.

The Air Corps plans to either develop or secure a fuel system that will avoid vapor locking, at least as regards the pump, with fuel having a Reid vapor pressure of 16 to 17 lb. per sq. in. at 100 deg. fahr. The Phillips Petroleum Co. is cooperating with the Air Corps by supplying for these tests a mixture of normal and iso-pentanes boiling over a range of 86 to 100 deg. fahr. It is possible that, while pump vapor-locking with such fuel can be avoided, carbureter float-bowl and jet vapor-locking of such magnitude as to prevent engine operation may occur.

Even if the fuel systems are improved so as to allow of vapor pressure considerably in excess of 6½ lb. Reid vapor pressure, it is possible that any considerable increase will be undesirable on account of fuel boiling in the tanks of supercharged airplanes, which may reach 30,000 ft. altitude in 20 min. with virtually no reduction of temperature of the fuel in the tanks. Provision of fuel-cooling measures would, of course, have an effect in this connection.

Bridgeman and Aldrich have shown[3] that in propane-free gasolines, the 10-per-cent-evaporated point gives a very close estimate of the vapor-locking temperature of the gasoline at a pressure of 760 mm. of mercury. Apparently the Air Corps is receiving gasoline containing propane, as the Reid vapor pressure at 100 deg. fahr. of samples of D.A.G. with almost identical 10-per-cent-evaporated points differs by as much as 1½ lb. per sq. in.

The specification of an upper limit of 167 deg. fahr. on the 10-per-cent point in conjunction with a Reid vapor-pressure requirement of 6½ lb. per sq. in. maximum at 100 deg. fahr. in Army Specification Y-3557-A should, theoretically, provide better control of starting quality than is obtained by the temperature limits of 122 to 167 deg. fahr. for the 5-per-cent-recovered point in the Federal Domestic Aviation Gasoline Specification. In practice, however, gasoline meeting specification Y-3557-A will be likely to possess poorer starting characteristics, as average D.A.G. has at present a 10-per cent-evaporated point of 140 deg. fahr. or below, and this results in a higher vapor pressure than 6½ lb. Reid.

The work of Bridgeman and his co-workers[4] at the Bureau of Standards, to which reference has been made, is to a very large degree responsible for the present efforts of the Air Corps to control vapor lock in airplanes, both in the matter of vapor pressure of gasoline and revision of fuel systems.

Gum

While cracked gasoline has been little used for aircraft purposes, there would seem to be little reason for excluding it without extensive tests. The Materiel Division has carried out endurance tests in flight with cracked aviation Ethyl gasoline and found no undesirable effects from the use of a cracked base. The fuel used in these tests was admittedly low in gum (below 10 mg. glass-dish test after accelerated aging with oxygen) and quite gum-stable. Several gum-stable cracked aviation gasolines of high antiknock value from a variety of sources have been tested by the Materiel Division.

The present Federal specifications of 3 mg. of copper-dish gum for aviation gasolines virtually exclude all cracked gasolines and are not very generally met by much of the straight-run fuel in use, and a glass or porcelain-dish requirement seems to provide no control of gum stability. The Materiel Division has tentatively specified an accelerated aging test with oxygen in Specification Y-3557-A and is financing an investigation at the Bureau of Standards of the relation of accelerated aging tests to storage conditions. This investigation would appear to be of such fundamental importance to the oil industry at large that it should be supported by the industry and its financing not be left to the Air Corps alone.

Available Fuels and Antiknocks

Ample supplies of Fighting Grade gasoline having an approximate antiknock value of 70-75 octane, 25-30 heptane of both gum-stable cracked and straight-run types seem to be available. Most of the straight-run stock available is, as far as the experience of the Materiel Division goes, of California origin. When anti-

[3] See Properties of Gasolines with Reference to Vapor Lock, S.A.E. JOURNAL, July, 1930, p. 93.

[4] See Vapor-Locking Tendencies of Aviation Gasolines, S.A.E. JOURNAL, August, 1930, p. 218.

knock values of the order of 87 octane 13 heptane are required, the use of tetraethyl lead and aromatics for addition to such bases appears to be the best present method of obtaining them. Benzol, which appears to be relatively ineffective at high cylinder-temperature, cannot be used in concentrations much in excess of 20 per cent on account of ice formation in the induction systems and freezing in the fuel systems, and even 20 per cent is troublesome. A freezing-point of —75 deg. fahr. for the finished fuel-blend seems to be about the upper limit for satisfactory operation, and a freezing point of, roughly, —150 deg. fahr. is to be desired. Aromatics of low freezing-point, synthesized from benzol, appear to be the only antiknocks of possible general availability other than dopes for the raising of the antiknock value of fuels of the bases discussed to ratings of the order of 87 octane 13 heptane.

Of the dopes, tetraethyl lead is at present the only one of interest for large-scale use. Some present types of aircraft engine develop troubles when operated on fuels containing tetraethyl lead. Several, however, are virtually free of operating trouble from this cause. Engines requiring fuels with antiknock ratings of the order of 87 octane 13 heptane are all of the super-performance type for military use, and the troubles arising with lead are vastly less difficult to overcome than those caused by insufficient antiknock value. For the present, the Air Corps is requiring that super-performance engines developed for its use shall operate satisfactorily on fuel containing 6 cc. of lead per gallon.

The Air Corps feels that operating troubles due to lead have been overcome in automobile engines and can equally be overcome in aircraft engines. From the experience of the Air Corps all troubles resulting from the use of lead in aircraft fuel apparently can be overcome by design, material and lubrication changes.

Variety of Fuels Available if Doped

Under the high-temperature conditions of knock test specified in Specification Y-3557-A, very large supplies of straight-run California gasoline that will meet the antiknock value required with less than the allowable maximum lead-concentration of 6 cc. per gallon appear to be available. Straight-run gasolines from other crudes that will meet the requirements of this specification also seem to be available in considerable quantity. If the Reid vapor-pressure requirement can be raised to about 10 lb. per sq. in., narrow cuts from Mid-Continent sources and having a boiling range of approximately 120 to 220 deg. fahr., with lead added in concentrations of 6 cc. or less, that will readily meet the antiknock requirement of 87 octane 13 heptane, appear to be a possible alternative to the use of base fuels from the crudes giving better antiknock values with normal distillation ranges. Narrow cuts consisting almost entirely of paraffins, when lead is added, make excellent fuels for hot-running engines as far as antiknock value is concerned, the antiknock value in terms of heptane octane being but slightly affected by variation of cylinder temperature, even with much more drastic conditions than those specified in Specification Y-3557-A.

Cracked Gasolines Respond Poorly to Lead

Knock tests of cracked gasolines without lead additions as against the best of the straight-run California gasolines without added lead, show that the cracked base is in cases superior in antiknock value. This superiority usually disappears when lead is added to both, as the cracked base with 10 cc. of lead added is at times inferior to the California base containing 3 cc. of lead. The lead response of some cracked fuels appears to be slight and in other cases to be virtually nil after a fairly low concentration has been reached. Knock tests of a more drastic type and agreeing more closely with multicylinder-engine results serve to make the lead response of cracked gasolines of present types even poorer.

Recent experience at the Materiel Division has served to create doubt as to the relative usefulness of base fuels containing unsaturated compounds which may be due to cracking or the presence of aromatics in straight-run fuels with or without added benzol. Unsaturated compounds appear to lose their antiknock effect in aircraft engines operating with high charge-density produced by either supercharging or high compression. This loss of antiknock effect is apparent in California gasoline-benzol-lead blends, even in highly supercharged water-cooled engines. In hot-running engines, unsaturated compounds in the base fuel with or without lead additions are relatively ineffective.

Corrosion troubles arise with the use of Ethyl gasoline in some aircraft engines, but corrosion due to fuel is by no means always the result of the use of lead. A recent case of violent engine-corrosion at the Materiel Division was traced to high-sulphur benzol. The Air Corps, as a result of this case, does not feel that the present sulphur limit of 0.1 per cent for the finished fuel can be raised nor the copper-dish corrosion-test be abolished.

Volatility Requirements *of* Aircraft Fuels

By J. H. Doolittle[1]

HIGHER volatility is required in an aircraft-engine fuel than in the ordinary internal-combustion-engine fuel, and provision must be made for easy starting, good distribution, freedom from vapor lock and decreased fire hazard. Each of these requirements requires the evaporation or non-evaporation of a certain percentage of the fuel under given temperature and pressure conditions that vary from one engine to another and with atmospheric-temperature changes. Changes in fuel volatility to suit the engine have no appreciable effect on performance, but small differences in the engine, particularly in the induction system, greatly overshadow any change that might occur in volatility.

[1] Manager of aviation department, Shell Petroleum Corp., St. Louis.

The ideal fuel is one whose boiling point is sufficiently high to avoid vapor lock and minimize the fire hazard but which will evaporate approximately 20 per cent at the initial boiling-point. A more complete removal of the hump in the distillation curve without lowering the initial boiling-point will give better starting and warming-up characteristics.

ONE of the major points of difference between an aircraft-engine fuel and an ordinary fuel is that higher volatility is required in the former. The four principal factors that make the aircraft engine dependent to a greater or lesser extent upon the volatility of the fuel are: (*a*) the ease of starting, (*b*) distribution, (*c*) freedom from vapor-locking troubles and (*d*) the fire hazard. Each of these demands that a certain percentage of the fuel shall or shall not be evaporated under a given set of temperature and pressure conditions. Unfortunately, these conditions vary widely, due not only to the wide variation of atmospheric temperature under which the aircraft engine is operated, but also from one engine to another, according to its design and method of installation. On the other hand, the small changes in the volatility of gasoline to suit the airplane engine fortunately do not appreciably affect its performance in the engine, but small differences in engine design, especially in the induction system, far overshadow any change that may be made in the volatility of the fuel. We are able, therefore, to arrive at a satisfactory specification for fuel volatility from a careful study of typical designs of fuel-feed system and manifold construction and a knowledge of the fundamental requirements of these features with respect to the quantity of fuel that must be evaporated in these systems at their working temperatures to give satisfactory performance. The problem resolves itself into two phases: First, a study of the fundamental volatility-characteristics of any given fuel, that is to say, how any given fuel will evaporate under any given condition as regards temperature and pressure, and the various means of measuring these fundamental volatility-characteristics, and, second, the question of the practical application of these volatility characteristics and their effect on engine performance, such as easy starting and good distribution.

Study of Fundamental Volatility-Characteristics

Let us consider briefly the first phase of our problem: In an aircraft engine, fuel is evaporated in the presence of varying volumes of air at various temperatures and pressures. Obviously, therefore, a fundamental study must be based on the tendency of the fuel to escape into the vapor state at various temperatures under definite conditions as regards the volume of air present and under equilibrium conditions, or, in other words, the actual basic measurement of the volatility of the fuel is an equilibrium-air-distillation curve. This curve is not a very easy one to determine, involving, as it does, the use of a large amount of complicated apparatus and highly skilled technique. Fortunately, however, for the petroleum industry, Dr. O. C. Bridgeman, of the Bureau of Standards, has done considerable work on this subject and has found that this curve can be computed with a certain degree of accuracy from the ordinary A.S.T.M. distillation curve, between 10 and 90 per cent evaporated, and actual measurement of the volatility of a fuel is now practically a solved problem.

We have, however, yet to consider the technical application of this volatility and in this connection a wide field for discussion exists. As mentioned, the basic method of measuring the volatility of a fuel is the equilibrium-air-distillation curve and we will consider the practical application of volatility from this basis. In any given engine a definite percentage of the fuel must evaporate under certain given temperature-conditions to give easy starting and good distribution. On the other hand, the initial fractions of the fuel must not evaporate too easily or we are apt to have vapor-locking trouble. That is to say, the flow to and through the carbureter jet will not be large enough to assure a proper working mixture in the manifold of the engine and also will greatly increase the fire hazard in case the airplane should crash.

In starting, practically every engine is primed by injecting a small quantity of fuel into the inlet manifold, close to the inlet valve, so that when the inlet valve opens liquid gasoline is drawn directly into the cylinder. To be able to get an explosion we must have in the cylinder near the spark-plugs at least 1 part of fuel vapor to every 20 parts of air, which means that if by priming we supply to the cylinder 1 part of liquid fuel by weight to every 3 parts of air, then 15 per cent of our fuel must evaporate under the temperature and pressure conditions existing in the cylinder for the engine to start. If, however, our fuel is not sufficiently volatile for 15 per cent to evaporate under these conditions, we must supply a greater proportion of fuel to air to start. We cannot, however, continue priming indefinitely because we will eventually inject so much gasoline that the oil will be washed off the cylinder walls, the compression lost and further difficulty result. This often happens in very cold weather. Suppose we supply a mixture of equal parts by weight of liquid fuel and air to the cylinder, we need only evaporate 5 per cent of our fuel. However, if our given priming arrangement supplies, under starting conditions, a 1:1 fuel-air mixture and 15 per cent evaporates at the manifold temperature, the resultant air-fuel vapor mixture-ratio will be $6\frac{2}{3}$ to 1, which is too rich to give an explosion. This represents over-priming or flooding and is common in a hot engine or in very warm weather. We see, therefore, that the percentage required to be evaporated depends upon the quantity of fuel injected. In very cold weather, evaporating will be difficult. In hot weather 30 per cent might evaporate and extreme care must be exercised to avoid over-priming. That is to say, the percentage to be evaporated depends upon the working temperature and pressure conditions in the engine, which are dependent almost wholly upon the atmospheric conditions under which the engine is being started and vary enormously.

Securing Maximum Performance

Having obtained our initial start, we must consider the problem of obtaining maximum performance as quickly as possible, and to get this performance and at the same time not run the carbureter at an unnecessarily rich mixture-strength, with a consequent crankcase-oil dilution, a somewhat larger proportion of the gasoline must evaporate. Suppose, for instance, we mix a small quantity of very light material such as ether or propane-butane mixture with a considerable quantity of heavy material, or, in other words, use a fuel with a steeply rising distillation curve. To make a small quantity of light components evaporate and so

make the initial start possible would then be easy, but relatively high temperature would be required before the component could be evaporated, and with such a mixture a very rich mixture must be supplied from the carbureter during this period to supply enough of the very light material to the cylinders. To provide a fuel that has a small quantity of very light material and a larger quantity of medium light material which will not require a high temperature for evaporation is desirable, therefore, so that after the initial start the engine needs only to be warmed up for a short while to get maximum performance without supplying an excessively rich mixture from the carbureter. Reducing this factor to a definite percentage required for evaporation as is the case with the initial start is not possible, since the conditions under which the fuel evaporates are constantly changing from the time of the initial start until the time when the engine is fully warmed up and ready to deliver its maximum power-output.

In addition to this considerable depends upon the ability of the carbureter to supply an even mixture-ratio over a wide range of speed and the ability of the induction system to deliver this mixture ratio evenly to each cylinder. Clearly, much also depends upon the time in which the engine attains its normal working-temperature. As a broad generalization, however, we may say that the smoothness of operation, the time to warm up and the crankcase dilution during the warming-up period depend upon the temperature necessary to evaporate about 60 or 70 per cent of the fuel. Here again the temperature at which this percentage should be evaporated must be based largely on careful reasoning and might also, with advantage, vary slightly with the atmospheric temperature.


J. H. Doolittle

We now have to consider the question of the importance of the volatility of the fuel when the engine is fully warmed up and delivering its maximum power-output. To obtain the best possible fuel-consumption consistent with maximum power-output, each cylinder must receive a uniform ratio of fuel and air at every suction stroke independently of the speed of the engine and atmospheric pressure. This means that not only must the carbureter deliver an even mixture-ratio from the jet at all air-speeds and pressures, but also the induction system must distribute this mixture evenly to all cylinders.

In airplane engines this is particularly difficult due to the unusual nature of the induction system. Again, to obtain the maximum possible volumetric-efficiency and so obtain maximum power-output, we must keep the external heat-input down to the least possible quantity, supplying just enough to overcome troubles due to ice formation on the carbureter and throttle. The greater portion of the fuel must evaporate in the manifold to obtain good distribution under normal working-temperatures; that is, the percentage evaporated required is practically 100 per cent and, therefore, the point of the continuous-distillation curve which would give us the best measure of the volatility of the fuel in this respect is the 100-per-cent-evaporated point or the dew-point. The dew-point temperature should be kept sufficiently low to make sure that the greater percentage of the fuel will evaporate under the relatively cool conditions that should exist in the average airplane-engine induction-manifold.

Temperature at Which Evaporation Occurs

To sum up so far, at the start we will require a small percentage, say some 20 per cent, to be evaporated under varying temperature-conditions. The selection of the temperature at which this percentage should be evaporated is dependent primarily on the atmospheric temperature and might with advantage be made flexible, depending on this temperature.

To be sure that only a short time elapses before the engine starts running normally without undue use of the primer, some 60 or 70 per cent of the gasoline should evaporate at relatively low temperatures. These depend more on the design of the engine, manifold, heater, and the like, than on atmospheric temperatures, and having specifications to take care of variations in atmospheric temperatures in this respect is not necessary.

In dealing with the problem of the performance under normal working-conditions, the dew-point or 100-per-cent-evaporated-point is probably the most important factor as regards the volatility of the fuel which will assure good distribution. But here again detecting small differences in the dew-point is impossible and the design of the induction system and carbureter and, to a large extent, the valve timing, are the most important factors that control the distribution efficiency of any given engine. However, to assure the best possible distribution-efficiency together with the maximum possible volumetric-efficiency, the dew-point of an aviation fuel must be considerably lower than that of an ordinary fuel to function satisfactorily in the relatively cool induction system of an aircraft engine.

Vapor Lock and Fire Hazard in Airplanes

In discussing the question of initial start, mention was made that if the fuel were too volatile and the engine over-primed, starting the engine might not be possible. Two further troubles, which may be encountered if the initial volatility of the fuel is too great, are vapor locking and fire hazard. The former has been recognized comparatively recently and considerable work has been carried out by Dr. Bridgeman of the Bureau of Standards in investigating the cause of this trouble. If the temperature of the liquid gasoline is such that the vapor pressure of the fuel exceeds the external pressure, then a bubble of vapor will be formed somewhere in the fuel-feed system or the jet of the carbureter, depending upon where that temperature is reached. This bubble of vapor may or may not cause trouble, depending on whether or not it hinders the flow of liquid gasoline through the jet. In some fuel-feed systems, considerable vapor can be formed in the float chamber of the carbureter or in the tank without affecting operation, due to the fact that the vapor is freely vented and does not stop the flow of liquid gasoline to the jet. Again, the flow may be restricted slightly provided the carbureter is set sufficiently rich that the mixture strength is not unduly weakened. However, as far as the fuel is concerned, the actual vapor-locking tendency appears, from

various experiments, to be related in the average case to the vapor pressure when measured in an apparatus that allows 2 or 3 per cent of the gasoline to evaporate. In other words, the vapor-locking tendency is probably best related to about the 2 or 3-per-cent point of the equilibrium-distillation curve, considering the design of the average fuel-feed system and history of the gasoline.

Since the danger of vapor lock as well as the ease of starting depends in large measure upon the atmospheric temperature, basing specifications concerning the lighter fractions of the fuel upon the atmospheric temperature and, in the case of vapor lock, the ceiling which we desire to reach is advantageous. The possibility of vapor lock also depends to some extent upon the location of the fuel tank, whether in the wings or fuselage, and whether a gravity feed or fuel pump is used in supplying the carbureter, since these factors control the temperature and pressure to which the liquid fuel is subjected before it reaches the carbureter jet. Vapor locking is much more serious in military than in commercial aviation, because in the former the gasoline tanks are almost always located so that a negative pressure-head exists on the intake side of the gasoline pump, especially when the gasoline is low in the tank, and also due to the greater altitudes at which military airplanes are obliged to operate.

The other danger that must be considered in connection with the lighter fractions of the gasoline is the possibility of fire in case of a crash if the fuel happens to come in contact with the hot exhaust pipe. While our control over this factor is somewhat limited, yet we can reduce the danger by maintaining as low vapor-pressure as possible to reduce the possibility of forming an explosive mixture.

Therefore, to avoid vapor-locking troubles with any given fuel system and to reduce the fire hazard to the minimum, we must keep the vapor pressure or the first 2 or 3 per cent of the equilibrium-distillation curve as high as is possible, consistent with the specification for assuring adequate starting, and these specifications can, with advantage, be made flexible, depending on the atmospheric temperature. From all of the foregoing the ideal fuel appears to be one that has a sufficiently high initial boiling-point to avoid vapor lock and minimize fire hazard; but, inasmuch as the starting characteristics of an airplane-engine fuel, especially in cold weather, are dependent more upon the temperature at which 20 per cent comes off than upon the initial boiling-point of the fuel, the more we remove of the hump in the continuous-distillation curve without lowering the initial boiling-point, the better starting and warming-up characteristics the fuel will have.

GENERAL DISCUSSION ON AIRCRAFT FUELS

CHAIRMAN W. L. SMITH[1]:—We have heard from an engine manufacturer, an operator, the oil companies and the Air Corps. I am sure we all feel deeply indebted to Mr. Heron for giving us of his time in this way, as everyone knows how much he means to all of our problems. After he wrote his paper originally, a lot of new information came to light, and he told me this morning that he rewrote the paper yesterday to include this new information. So you see that this subject of aircraft fuels is very new and much remains to be learned about it, as everyone has stated.

R. E. WILSON[2]:—One difficulty in following Mr. Heron in discussion is that he always leaves so little to be said. However, I jotted down from time to time a few notes of points I think ought to be amplified or possibly criticized.

Mr. Doolittle spoke of fire hazard as well as vapor lock being a danger from a gasoline of too high volatility. It seems to me that must be based on a misconception because any gasoline is volatile enough to ignite from sparks or a flame in the free air. About the only difference between gasolines as regards fire hazard is whether, at the temperature prevailing, the vapor space in the gasoline tank contains an explosive mixture. As a matter of fact, the more volatile gasolines are less likely to form an explosive mixture in the tank because they are very over-rich; only the comparatively non-volatile gasolines at rather low temperature will give a mixture lean enough to explode. Bearing that out, in our refineries we have a great deal more trouble with fires in crude-oil and heavy-naphtha tanks caused by lightning than we do in the gasoline tanks, because in the latter the mixture is almost always too rich to propagate an explosion.

Gum-Content Limit Too Low

Considerable reference has been made to the difficulties caused by gum in gasoline. While it has been spoken of elsewhere, the attention of this meeting has not been called to that fact that there are methods of adding certain anti-oxidants or passivating agents to cracked gasoline which very greatly decrease the tendency to form gum on storage; in fact, a cracked gasoline can be made virtually as stable as straight-run gasoline. It also seems in general that gum formation and the loss of antiknock quality are problems that go hand in hand; that is, gasolines that tend to form gum on storage also tend to lose antiknock quality on storage, and vice versa. Both are evidently due to oxidation phenomena and both can be prevented by the use of anti-oxidants.

R. E. WILSON

Mr. Larson, of the Sinclair Refining Co., spoke about making a test on a gasoline which showed 40 mg. of gum per 100 cc. by the copper-dish test but gave no deposit in the engine. It has been pointed out previously that the copper-dish test bears no relation to gum deposition in the engine, but indicates very roughly how much gum might form on long storage. A gasoline with a high

[1] A.S.A.E.—Chief engineer, National Air Transport, Inc., Chicago Municipal Airport, Chicago.

[2] M.S.A.E.—Assistant to vice-president in charge of manufacturing, head of development and patent department, Standard Oil Co. (Indiana), Chicago.

copper-dish gum test may give no deposit when fresh, yet the same gasoline three months later will form a deposit. To say that a gasoline of a certain copper-dish test deposits no gum is meaningless. The copper-dish test gives some idea as to how much gum is likely to form on storage, but if one desires to determine how much actual gum has been formed in the gasoline at a given time and how much deposit he is likely to get in an engine he must use a gum test that measures the gum that is actually present in the gasoline, which means a test which evaporates the gasoline in the absence of air. I feel sure that, if any substantial quantity of gum, even approaching 40 mg. of actual gum, is really present in the gasoline, there is no question that it will cause serious deposits in the engine. Nevertheless, I do think that the present limit of 3 mg. of gum per 100 cc. in the Army specifications is too low to permit the development of improved types of antiknock fuel at lower cost than would otherwise be possible.

Vapor-Pressure Limit Penalizes Army

With regard to the limit on the vapor lock of 6½-lb. vapor pressure, it must be kept in mind that any limit as strict as that, in spite of the fact that it is probably necessary to meet certain existing conditions as to vapor lock, interferes both with the ease of starting and the antiknock value of the gasoline that can be supplied. In almost every type of gasoline, the more light ends that are present the better the antiknock value. I certainly hope the Army will push its work on improving fuel systems, for it is penalizing itself if it insist on a vapor-pressure limit as low as 6½ lb.

Mr. McVitty, of the Pan American Airways, mentioned the evaporation losses during storage in hot climates, caused by vapor expansion in a drum that is heated by the sun followed by contraction at night. I should think he would find it very desirable, from the standpoint both of saving money and of preventing a change in the composition of the gasoline, to adopt either the floating roof or the breather-bag method of protecting storage, which virtually eliminates such losses.

Research Has Resulted in Better Fuels

EDWARD P. WARNER[3]:—The present state of the business of supplying fuel to aircraft operators seems to me to be a beautiful proof of the fact, which some of us may doubt from time to time, that if the technicians talk about a thing long enough they finally begin to get somewhere. It is rather satisfying to reflect on the effect that the interests and activities of the S.A.E. have had on this question of fuel supply and on the development of standard grades of fuel and the determination of what is wanted for the actual type of vehicle that is being used, whether in the air or on the highway. A so-called Cooperative Fuel Research, in which Mr. Wilson and other members of the Society have been very active, has been going on for a number of years under various guises. It has been carried on largely under the immediate direction of Dr. H. C. Dickinson, H. K. Cummings and others of the Bureau of Standards. That has been directed primarily to fuel for the highway vehicle, but it certainly has given a starting point and established the springboard, so to speak, from which we can take off for really useful manifestation of the Society's interests in aircraft fuels.

We have been talking about aircraft fuel at Society meetings for several years. At the Chicago meeting in the fall of 1928, at the time of the Aircraft Show out there and just before the International Air Congress, a rather prolonged discussion of this subject of fuels and especially of higher grade fuels was held. At that time considerable skepticism was expressed by representatives of interests both in the aircraft industry and in the oil industry regarding the desirability of seeking for a much higher performance than was then obtained from the standard gasoline, the Domestic Aviation Grade, that was being generally furnished and used. I remember talking at that time with an executive of one of the engine companies who told me that he thought the fact of which the American services could be proudest was that they had insisted that no fuel better than D. A. G. was going to be used as the standard of development and that every engine would have to be adapted to run satisfactorily on that grade of gasoline.

EDWARD P. WARNER

Some of us did not think in 1928 that this was anything of which to be particularly proud. We have come a long way since then and are on the right road. First, we are getting a better fuel, and, second, we are giving the engine designer the opportunity of coming up to the best that the oil industry can provide. I was interested to note that among Mr. Larson's five categories of demand for aircraft fuel, the lowest, the group which wants to use only D. A. G. according to the so-called Department of Commerce specification, seems, so far as Mr. Larson recited the reasons, to base that desire solely on sentimental grounds.

As a matter of fact, I think we have not gone far enough yet. There seems to be more that we can legitimately hope to accomplish, and I think that we shall keep upon the right road if we eliminate sentiment and speculation and make as close an analysis as is possible by mathematical means. After all, this is simply an economic question. Aircraft engines can be built that will run on something very much worse than D. A. G. The operation of farm tractors every day proves that gasoline engines can be built that will run on something that we hardly call gasoline and that will develop, say, 100 hp. for a certain unit consumption of fuel and for a certain weight of engine and a certain frontal area. We can then design engines to run on D. A. G. at a lower consumption, a lighter weight of engine and a smaller frontal area. Then we can produce a better grade of gasoline and economize still further on the engine and on the weight of fuel that has to be carried.

That is a question that can be attacked by analytic methods and one to which we can get an answer. I am not going to give at the moment what I think is the numerical answer. I have done some work on the sub-

[3] M.S.A.E.—Editor, *Aviation*, New York City.

ject and hope at some time to have the opportunity to present a paper on it. I worked out a formula about two years ago that seemed to me to correspond in value in general to the needs of the commercial aircraft operator in the reduction of fuel consumption and of frontal area. I sent that formula to Mr. Wilson and asked him what the refiner would be justified in offering on the condition that a certain saving in unit consumption or in weight and frontal area per unit of power is worth 1 cent per gal. additional on the price of the fuel. His reply was that the refiner could not possibly think of anything to do that would not be worth while on that basis, and that we could hope for substantially better fuels if the aircraft operators would accustom themselves to paying the cost. We can get a fuel for, say, 9 or 10 cents per gal. that will do certain things. If we pay 5 cents more, we can get one that will do more. It is simply a question of how far we should go. Personally I think it is worth while going much farther in the improvement of engines and fuels than any body has seriously attempted to go as yet.

Higher-Priced Fuel Saves Operator Money

CHAIRMAN SMITH:—I quite agree with the last statement made by Mr. Warner. Our company has recently made a change from the fuel it was using. We are paying more for our fuel now than formerly and are making more money as a result. We have less trouble with our engines and the fuel consumption has gone down a little. We see that we can go further and I think we shall when we can obtain the right engines. The fuel companies have worked very well with us and are giving just the sort of fuel we want. Probably we can get better fuel now than we can use efficiently. The next step will be to have the engine manufacturers produce engines that will burn these better fuels economically and efficiently.

J. H. GEISSE[4]:—President Warner is trying to find by a formula how much premium we can pay for antidetonating fuel. The formula is going to depend entirely upon the kind of service one is talking about, because economy is not only a question of saving in fuel consumption but also in the cost of carrying the fuel. That depends on the number of hours of operation and quite a difference in premiums can be paid for antidetonating fuel by a man who is going to fly for about an hour and a transport company that has to fly its transports for 6 hr.

Benzol and Tetraethyl Lead Work Differently

Mr. Heron brought out the point that benzol and tetraethyl lead work very differently in their antidetonating characteristics according to the temperature. Most of his tests were based on increasing the cylinder-head temperature, which undoubtedly is the correct procedure. But we must remember that this is a little different than the study of detonation itself. Benzol will cause an increase in cylinder-head temperature independently of detonation, as can be seen in the curve that Mr. Parkins gave in his Fig. 3, in which a considerable drop in head temperature occurred with the addition of a certain quantity of benzol. As the quantity of benzol was increased, the cylinder-head temperature traveled up again. That is characteristic of benzol even when the engine is free from detonation. The more benzol that is put in, the higher the temperature will go. I do not know why this is so.

Regarding gum content, I was greatly interested in hearing Mr. Wilson say that they have a means now of preventing the cracked gasolines from decomposing. The measure of simply the gum content in the gasoline at the start is, as he said, of absolutely no value. I have had cracked gasolines which had a very good gum-content originally but which did not have to go into an engine at all to deposit a gum. We could not pump them out of the tank after a period of storage. We had to put in benzol and alcohol to dissolve the gum formed.

Mr. Heron mentioned that with benzol, in addition to the increase in cylinder-head temperature, he had some after-fire. That again is an entirely different problem than detonation. The different fuels have entirely different ignition-points. The straight gasoline or normal gasoline requires a fairly high temperature to ignite it, whereas benzol can be ignited, I think, without a spark-plug at a compression ratio of about 14:1. If the engine is just motored over long enough it will start to fire. That cannot be done with gasoline.

It is absolutely essential that we find some standard method of rating gasolines, some organization that will test the gasolines and rate them. The S.A.E. has been working on this. I had a very surprising experience a little while ago. I told a dealer that I wanted some ordinary gasoline, not a good gasoline, because we were to use it for test and I wanted about the worst we would be likely to get. He gave me some which I sent to the Navy to test, and I was greatly surprised to learn that it is possible to make a Domestic Aviation Grade that is worse than the East Coast D. A. G. It was necessary to add something like 20 per cent of benzol to the gasoline to make it compare with the East Coast D. A. G. Nevertheless, that fuel is being sold at that airport. The men there had no idea of what detonation is. They compared the fuel with automobile gasoline, which was antidetonating fuel, and thought this was better; as a matter of fact, it was poorer.

E. E. ALDRIN

G. G. BROWN[5]:—Mr. Aldrin remarked that occasionally the 90-per cent point on the A.S.T.M. distillation curve might be far more significant as indicating vapor lock than the vapor pressure of gasoline. Will he amplify that?

End-Point and Vapor Pressure as Indicators

E. E. ALDRIN[6]:—What I meant to say was that the 90-per cent point or the end-point may have just as much effect on the vapor-locking tendency of the gasoline as the vapor-pressure values that are obtained at 100 deg. fahr. I know of two gasolines that run on 8-lb. Reid vapor-pressure; one has an end-point around

[4] M.S.A.E.—Vice-president in charge of engineering, Comet Engine Corp., Madison, Wis.

[5] M.S.A.E.—Professor of chemical engineering, consulting engineer, University of Michigan, Ann Arbor, Mich.

[6] M.S.A.E.—Aviation manager, Standard Oil Co. of New Jersey, New York City.

330 deg. and the other an end-point around 270 deg. In the same type of installations and under similar conditions, the latter gave vapor-lock trouble and the former did not. I point this out to show that there is doubt as to the real value of Reid vapor pressure.

Airlines Find 9½ Lb. Vapor Pressure Safe

PROFESSOR BROWN:—My experience has been that there can be rather large differences in the 90-per cent point with about the same 10-per cent point and same vapor pressure, and the fuels will show about the same tendency to vapor-lock. Possibly in these tests that Mr. Aldrin is referring to other factors may have entered and the blame may have been placed upon the 90-per cent point rather than upon another factor.

The Army is clearly penalizing itself in volatility by going to extremely low vapor pressures. The ordinary commercial flying planes using either gravity or pump feed seem to be able to use satisfactorily at the present time fuels having a vapor pressure running in excess of 10 lb.; in fact, last winter many oil companies were actually selling satisfactory aviation fuel having vapor pressures running as high as 11 lb. per sq. in. at 100 deg. fahr.

Since a vapor pressure of 9½ lb. seems to be adequately safe for the commercial airplanes now in use, the differences in the way the fuel tanks are laid out and the location of the fuel pumps must be responsible for the trouble experienced by the Army. If possible, it would be highly desirable for the Army to adopt a fuel system that would handle a satisfactory commercial fuel as well as do the commercial airplanes. If there are enough differences in the design of the airplane fuel systems to make necessary a 6½-lb. maximum vapor pressure, when 9½ or 10½-lb. vapor pressure is otherwise satisfactory, it is time to give more attention to the fuel system as a major factor in causing vapor lock, rather than to place the blame entirely upon the fuel.

G. G. BROWN

E. W. ZUBLIN[7]:—I should like to corroborate Professor Brown's statement. Fuels of 9 and 9½-lb. vapor pressure were widely used in Oklahoma and Texas last summer. To my knowledge not a single serious case of vapor lock developed. From what Professor Brown and Mr. Wilson have said, vapor lock has been greatly exaggerated and nothing should be sacrificed for the sake of avoiding vapor lock.

MR. GEISSE:—I should like to come to the defense of the Army and the Navy. The fuel systems are rather well defined by other characteristics of the planes. The Army and Navy are almost compelled to use a fuel pump, and when a fuel pump is used you are interested in vapor lock. Virtually all of the commercial airplanes have gravity feed, and, so far as I know, vapor lock is almost impossible with gravity feed.

[7] Chief chemist, Texas Pacific Coal & Oil Co., Fort Worth, Texas.

[8] S.M.S.A.E.—Research associate, Bureau of Standards, City of Washington.

Temperature in Fuel Tank Controls Vapor Lock

O. C. BRIDGEMAN[8]:—The problem of vapor lock in airplane fuel-systems can be stated very simply. From the work we have done at the Bureau of Standards, the temperature of the gasoline in the tank as it leaves the ground seems to be the controlling factor. Unquestionably, there are variations in fuel systems, but that fact is far overshadowed by the temperature of the gasoline in the tank as it leaves the ground.

Roughly, the temperature at which vapor lock will occur decreases 2 deg. fahr. for every 1000 ft. of altitude, so at 18,000 ft. it would be 35 deg. lower. If the gasoline in the tank leaves the ground at 100 deg. fahr., which is not unusual, it will have to have a 10-per cent point higher than 135 deg. fahr., otherwise vapor-lock trouble will occur in general. Therefore, if the temperature in the tank when the ship leaves the ground is known, one can tell fairly well what the 10-per cent point must be or what vapor pressure is allowable.

A 135-deg. 10-per cent will correspond to a little less than 8-lb. Reid vapor pressure, so Mr. Heron's statement of 6½ lb. will probably apply all right to very-hot-weather flying. On the other hand, if flying in the winter, the temperatures could be considerably lower and the Reid vapor pressures could be higher.

While the problem is largely one of the temperature in the tank, I think far too little is known about what temperatures should exist in airplane fuel-systems. These temperatures are very difficult to take. Very few airplanes have fuel-temperature measuring instruments in them. In most of the tests we have made, the temperature does not vary greatly between the tank and the carbureter—perhaps 10 deg. fahr.—but the fall in temperature in the tank does vary considerably as the plane gains altitude. In some tanks that are well insulated thermally the temperature does not change, or changes very little, in going rapidly up to 15,000, 18,000 or 25,000 ft. In others the temperature changes rapidly. That, it seems to me, is the major fact in connection with airplane fuel-systems that needs to stressed; the temperature of the gasoline in the tank at the ground should be kept as low as possible and the tank should be in as good thermal contact with the atmosphere as possible so that the temperature will drop as the ship gains altitude. In that way I think we can do as much to counteract vapor lock as we can do in the matter of improving the fuel to prevent it.

CHAIRMAN SMITH:—We have had four cases of vapor lock in commercial airplanes in the Southwest in the last 60 days. The fact that we are using Fighting Grade gasoline probably has something to do with it. In fact, we had to turn one tank of gasoline back to the producer because the 10-per cent point was too low for any of us to consider. Although we have been constantly redesigning our fuel systems until we have evolved one that worked very well under most conditions, and that has given us less trouble, I think, than almost any other type of fuel system, yet, when we started using Fighting Grade, we had vapor lock. It always happened during the daytime; never at night.

Our airplanes fly through several stations and take on fuel at them. The particular mixture that is in the fuel tank at any given time depends on which station the plane visited last. The fuel at different stations is supplied by different companies.

No C. T. S. and Antiknock-Value Relationship

S. D. HERON[9]:—While it is possible to agree with Mr. Larson's laments concerning the demands for so many grades of aviation gasoline, the reverse is true regarding his conclusions on the technical side of the matter. It is unfortunate that it is not possible adequately to control the quality of aviation gasoline by methods possessing the delightful simplicity proposed by Mr. Larson; that is, relating antiknock value to the C. T. S. (critical temperature of solution in aniline) and specifying 20 mg. of gum per 100 cc. without any question of the stability in storage.

Mr. Larson seems to regard the critical temperature of solution in aniline of a fuel as an index of its antiknock value. The Air Corps has specified a C. T. S. after nitration of 62 deg. cent. (143.6 deg. fahr.) as the maximum for D. A. G. procured to its Specification 2-40F, and this has served the purpose of excluding the very badly knocking gasolines.

Despite the use of a C. T. S. value in Specification 2-40F, it is impossible to defend its use on scientific grounds. The Materiel Division of the Air Corps has not found any relation between the C. T. S., either before or after nitration, and antiknock value, particularly when the latter is obtained at high cylinder-temperature. The addition of a relatively small percentage of aromatics to a straight-run gasoline of low antiknock value serves to sharply depress its C. T. S. value but at high cylinder-temperature is almost without effect upon its antiknock value. As far as the somewhat meager observations of the Materiel Division go regarding the value of C. T. S. in relation to antiknock value, it suggests that a small change in C. T. S. as a result of nitration is indicative, first, that the gasoline is not subject to much change of antiknock value in terms of heptane octane with variation of cylinder temperature; and, secondly, that the lead susceptibility will be high.

That relating the C. T. S. to antiknock value is completely unsound is demonstrated by the C. T. S. values of normal heptane and 2-2-4 trimethyl pentane. The C. T. S. of the former is 70 deg, cent.[10] (158 deg. fahr.) and of the latter 84 deg. cent.[11] (183.2 deg. fahr.).

Edgar and Calingaert[10] have determined the C. T. S. values for all the heptanes. Lovell, Campbell and Boyd, in a recent and as yet unpublished paper[12], have determined the relative antiknock values of all the heptanes when tested in dilute condition. Study of these data shows no relation between the C. T. S. and the antiknock values. As applied to the antiknock value of aircraft-engine fuels, the critical temperature of solution in aniline may be said to be almost worthless.

Mr. Larson states that "Fighting Grade gasoline has a better antiknock value than Domestic Grade." This may be so but is not always true of Fighting Grade produced by redistillation of a given Domestic Grade. The assumption that Fighting Grade is always better in antiknock value than D. A. G., irrespective of the crudes from which they are derived, seems to need no comment.

Mr. Larson's statement that the allowable gum-content should be raised to 20 mg. per 100 cc. is very decidedly open to question. Presumably he refers to copper-dish values on refinery samples. Gasoline meeting such a requirement may, and often does, develop such a quantity of gum in storage as to render it quite unusable for aircraft purposes in the light of present knowledge. His data on the 70-hr. endurance test would be of more value if the dissolved gum present at the time of the test were stated.

Mr. Larson also stated, in the course of the delivery of his paper, that "the required cooling-liquid temperature for testing aviation gasolines for antiknock value is 300 deg. fahr." It is doubtful whether it is at all positive that 300 deg. fahr. is the required temperature. The temperature required would appear to depend upon: (*a*) the test engine used, (*b*) the rate of revolution of the test engine, and (*c*) the type of aircraft engine in which the fuel is to be used.

C. M. LARSON[13]:—It is regretted that Mr. Heron was disturbed by the C. T. S. data shown in connection with the Navy specifications, as there was not the slightest intention to promote critical temperature of solution in aniline as an antiknock yardstick. It is true, however, that the Navy test data on the N. A. C. A. engine, which the Navy uses to determine antiknock ratings, gave for numerous samples submitted for approval the relationship of C. T. S. to compression ratios as plotted in Fig. 1 of my paper. Despite this, Mr. Heron will note that I recommend that the S.A.E. antiknock engine or its equivalent be the one to use in setting up the antiknock value and that such an engine should have provisions for using a cooling-liquid temperature of 300 deg. fahr. for testing aviation gasolines. Therefore I desire to clear up Mr. Heron's misconception by stating that the engine antiknock rating is the one recommended, not the critical temperature of solution.

Mr. Heron's comment on the Fighting Grade is best answered by stating that the opinion, "Fighting Grade gasoline has a better antiknock value than Domestic Grade," is not my personal view but, as the paper sets forth, constitutes that of one of the five groups which recommend a compromise.

In regard to Mr. Heron's statement on gum content and referring in particular to the figure of 20 mg. per 100 cc. based on the copper-dish test, no purchaser is in the habit of accepting shipments on refinery make but invariably checks actual deliveries of gasoline against specifications. If necessary, an accelerated aging test with oxygen stability could also be considered. However, these limits should be investigated by the Bureau of Standards or suitable parties authorized to draw up new specifications.

The dissolved gum present in the gasoline at the time of use in the 70-hr. endurance test was 3.1 mg. (steam oven), the gasoline having weathered 60 days in drums.

The question raised by Mr. Heron regarding the desirability of using 300 deg. fahr. temperature for the engine-cooling liquid while testing aviation gasoline for antiknock value is one that can best be answered by the Antiknock Fuel Committee of the Society. Surely not many laboratories are going to buy several engines costing in the neighborhood of $6,000 each. Whatever engine is adopted by the S.A.E. for motor

[9] S.M.S.A.E.—Research engineer, Materiel Division, Air Corps, Wright Field, Dayton, Ohio.

[10] See *Journal of the American Chemical Society*, May, 1929, p. 1483.

[11] Private communication from Graham Edgar, Ethyl Gasoline Corp., Yonkers, N. Y.

[12] See Detonation Characteristics of Some Paraffin Hydrocarbons, by Wheeler G. Lovell, John M. Campbell and T. A. Boyd, presented before the American Chemical Society, Sept. 11, 1930.

[13] M.S.A.E.—Supervising engineer, Sinclair Refining Co., New York City.

gasoline antiknock ratings should be flexible enough to run with a higher jacket-cooling temperature in order to permit its use for antiknock ratings of aviation gasoline.

I wish to repeat that the petroleum and aircraft-engine industries will welcome the Moses who will work out two grades of aviation gasolines, "one aviation gasoline with a reasonably high antiknock value, to be used for private flying and serial service as well as by scheduled transport consumers, and perhaps one other but not more than one additional specification to cover aviation fuel for the Army and the Navy and such scheduled transport lines and other consumers as may desire to use supercharged engines, all of whom find it necessary to go to compression ratios higher than 5.1:1 for air-cooled engines."

Until this is done, the oil **companies cannot afford** to plan National distribution for a demand equivalent to only that used by 50,000 automobiles.

Filtering Gasoline When Refueling

C. A. Bellows[14]:—Ever since the early start of aviation, the necessity for clean fuel has been appreciated and methods have been employed in an attempt to ensure that well-filtered water-free gasoline was delivered to airplanes. These methods were admittedly slow and unsatisfactory. The aviation section of the research department of the company with which I am connected, in conjunction with the engineering laboratories of the Standard Oil Development Co. and the aviation department of the Standard Oil Co. of New Jersey, has for a considerable time been making a careful study of the method of fueling airplanes so that equipment might be developed that would meet the demands of commercial aviation for the delivery of clean gasoline.

C. M. Larson

From the first it has been apparent that equipment for suitably removing all foreign matter from gasoline delivered to an airplane must not hamper the rate of flow, since definite schedules must now be complied with in commercial work and delays are expensive. To be most useful, a filtering device must be light and of as small dimensions as are practicable, so that it can be readily carried on the plane and be ready for service each time the airplane is refueled. Again, the filtering device must be so constructed that all hazard incident to the filtering operation is eliminated. With these thoughts in mind, the Gilbert & Barker filter funnel has been brought to its present form and is in use in many parts of the Country today.

To filter all gasoline through a funnel in which a piece of chamois was inserted was common practice in the early days of the automobile; and this method has been in use in aviation circles and is employed on many fields today. However, there are many variable factors in the use of chamois which make it inadequate as far as fulfilling the needs of commercial aviation today is concerned. First, passing gasoline through chamois generates static electricity and, while this static is harmless in itself if necessary steps are taken to dissipate it, it may become a source of extreme danger if it is allowed to accumulate through lack of effective grounding, as it may eventually discharge in the form of a spark. The possibility of the accumulation of such a static charge is readily eliminated by making a direct ground-connection between the funnel and the discharge nozzle of the hose. That is in accordance with the practice, long established in automotive fueling, of discharging gasoline through a metal-lined hose and maintaining a metallic contact of the hose nozzle and the funnel. The funnel rests in the opening of the metal gasoline tank and assures metallic contact. When chamois is used in a funnel, the act of making the necessary ground-connection requires a little time and thought, and because of carelessness the hazard involved through improper grounding may result disastrously. Therefore it became apparent that a funnel constructed so as to eliminate all hazard would be a step in the direction of improved refueling.

[14] Research engineer, Gilbert & Barker Mfg. Co., New York City.

Filtering Through Chamois

The delivery of gasoline at high rates of flow becomes more important with the advance of commercial aviation, hence the chamois funnel has become more and more inadequate. Chamois varies in its ability to pass gasoline. Good-quality chamois, when new, will pass about 3 gal. per min., whereas chamois of a poorer quality may pass as high as 10 to 12 gal. per min. In the latter case the speed of delivery is, obviously, obtained at the sacrifice of good filtering, since the poorer grade of chamois fails to extract all of the foreign matter. The expectation that a piece of chamois will be used for a considerable period of time is reasonable, and here again the variable factor of chamois filtering enters, because, with the extraction of water or other foreign matter from the gasoline, the pores in the chamois become filled and the skin which originally passed 3 gal. per min, will pass but 1 gal. or less after it becomes clogged with dirt. Even though the recovery is slowed up and the chamois has become less effective as a material for filtering the deliveries to large planes, it must be admitted that good-quality chamois is effective in recovering water from gasoline.

Although all possible precautions are taken to assure water-free gasoline leaving the refinery, moisture enters the storage and supply tanks, whether these are stationary or in transit, through the vents with which all tanks must be equipped. This moisture condenses in the tank and is picked up by the gasoline as it is withdrawn by the pumping unit. A few drops of water in the gasoline in an automobile will cause no great trouble, the chances being that, aside from a little sputtering of the engine, no inconvenience will be experienced. But the presence of just a few drops of water in the fuel tank of an airplane may cause disastrous results. The filter funnel previously referred to immediately detects the presence of water, and the operator has only to open a petcock and draw this water off while the fueling operation continues.

An Effective Filter Funnel

The funnel consists of an outer chamber having a cover and a bottom discharge-outlet arranged to receive 1½ or 2-in. outlet tubes. This makes it possible to refuel airplanes having any of the present-day tank open-

ings. Gasoline entering the opening in the cover passes down through six radially disposed tubes to the bottom of the funnel chamber. It then rises and passes through a 200-mesh screen surrounding the inlet tubes. After passing through this screen it travels downward through the bottom of the chamber and thence out through the discharge outlet first mentioned. A valve chamber having a normally open valve is situated in the discharge line adjacent to the funnel proper. This is an emergency valve that can be closed by a flip of the spindle lever in case the operator finds that the tank is about to overflow.

The effectiveness of this funnel, the construction of which is very simple, lies in the arrangement of its parts. The relative position of the inlet and discharge, together with the reversal of flow of the gasoline in passing through the device, tends to give the greatest efficiency in the separation of foreign matter. A glass-tube indicator is located at the side of the funnel near the bottom, and when water is mixed with the gasoline its presence is immediately detected in the funnel by watching the liquid in the tube. If the water is coming in any considerable quantity, the fueling can be halted momentarily and the water drained out, but under all ordinary conditions the funnel sump will retain all the water that may accumulate from any normal fueling operation, and this can be drawn off afterward without slowing up the delivery time.

The funnel itself is made of aluminum sheet, and the castings are of aluminum. The screen is of bronze and is firmly secured in position, assuring passage of all the gasoline through it.

The performance of this funnel proves that the vertically disposed screen, located in correct relation to the housing of the funnel, gives great efficiency in the filtering of gasoline when refueling airplanes.

Conclusions from Gum Tests at Variance

C. G. WILLIAMS[15]:—I desire to give some personal views on the subject of gum in gasoline which are the result of tests carried on during a period of five years. These opinions may be decidedly contrary to some findings presented in the paper on Gum in Gasoline[16], but, although my work was done with the aid of equipment of a very crude nature, I believe they are fair and conclusions arrived at may be very far-reaching.

Contrary to conclusions Nos. (1) and (2) in the paper mentioned, cracked gasoline, as it comes from the stills, is not free from actual gum, and, although it may seem to be free, in some cases a period of 2 hr. in a gasoline tank of an automobile or storage for 24 hr. in a tank car during transit will be sufficient for gum to collect and precipitate.

My contention is that the gum is in the gasoline at all times, that it is in the condition of unstable equilibrium or a supersaturated mixture, and that certain conditions only need to be satisfied to cause the suspended particles to coalesce and be precipitated on the walls of the containing vessel and of the combustion-chamber of an engine. They are deposited in the form of (*a*) a yellow glutinous wax and (*b*) a semi-solidified coke of the order of bituminous coal. The latter can be readily scraped off the chamber or valve and, when collected and ignited, will burn like cannel coal or oil coke, with a heavy black smoke. When in the form of a wax, the deposit will also burn but gives off a thin blue vapor that is astringent and of a very suffocating nature. It has no odor that I have been able to detect. It can be led through water and, when collected after washing, cannot be detected by any means I have had at hand.

Contrary to opinions expressed in conclusion (3) of the paper, this gum will form deposits all the way from the gasoline tank of an automobile to the combustion-chamber. When the gum is sprayed into the combustion-chamber with the gasoline, it does not retard combustion nor cause imperfect engine operation. In the tests mentioned, when using gasoline from which the precipitation was most abundant, the engine gave the most perfect operation of any time and more miles were obtained per gallon of fuel than was the case with other gasoline that gave but little or no precipitation, and always with the same setting of the carbureter.

Gum Creates Intense Combustion Heat

One phase, however, that has been overlooked is that the fire ring of the impregnated-gasoline charge gave off unprecedented quantities of heat in the combustion-chamber, the heat being so intense as to burn the tops of one or more valves, in one case to such an extent as to cause the valves to crumble under light blows of a hammer after having been removed from the engine. One valve was half burned away after only 2000 miles of use during the period when precipitation of wax from the gasoline in the tank and carbureter was at its highest point.

Use of this run of gasoline in a sleeve-valve engine caused the inner sleeve to be so badly burned that parts crumbled off the top. Some of these fragments were caught in the valve opening of the outer sleeve and resulted in pulling the lug off the bottom of the inner sleeve. When the engine was dismantled, the full extent of the injury to the sleeves became known. Recourse to another gasoline stopped the trouble with the sleeve-valve engine, but experiments were carried on with a valve-in-the-head engine.

Referring to the authors' conclusion (5), I have made but two tests to show the relative gum-content in any gasoline and did not derive any satisfaction from those made, as the quantity shown to be in the gasoline was no criterion of the amount deposited on the walls of the fuel tank, the combustion-chamber and the cylinder. However, the precipitation at all times appeared to be much in excess of 10 mg. per 100 cc. in the gasoline tank alone, without any reference to that which was present in the combustion-chamber and the portion that must have been burned.

One of my conclusions was that the wax carried a superabundance of oxygen that caused it to burn even when ignited in a partial vacuum under a bell jar. This may have accounted for the trouble that ensued after 5000 miles of operation of the Buick, as reported by the authors of the paper to which reference is made.

Thought To Be Suspended Amorphous Sulphur

I should like also to reply to the discussion of that paper contributed by B. P. Sparks.

In the many cases in which I have noticed this wax formation, it was of a yellowish color and of the consistency of soft wax when deposited in the gasoline tank, the supply tanks, the supply pipes and the car-

(*Concluded on p.* 715)

[15] M.S.A.E.—Chief engineer, Green Bay Barker Machine & Tools Works, Green Bay, Wis.

[16] See S.A.E. JOURNAL, January, 1930, p. 31.

Aircraft *and* Motor-Car Powerplants Compared

18th National Aeronautic Meeting Paper

By H. M. Crane[1]

APPROXIMATELY 15 years ago I was suddenly informed that I had to go to Paris with the president of the Simplex Company to select an aviation engine to be built for the French Government. I had built a vertical four-cylinder water-cooled aviation engine some years before and I doff my hat to Grover Loening, who designed the airplane, because he was actually able to get it off the ground under its own power. That engine was no light-weight job. This is merely mentioned as indicating the progress that has been made.

We arrived in Paris and were shown the Hispaño engine which was being considered by the Government at that time. It had been flown in one airplane but had not passed the 50-hr. Government test. The French Government preferred the Peugeot engine which was a development of a racing-car engine-design. This engine was interesting when we consider the relation between motor-car and airplane engines and also interested me because I have rarely believed what has been told me so frequently, that we owe our progress in automobile engines to the Indianapolis Speedway.

At that time, outside of building one aviation engine, I had taken very little interest in aviation. I looked at these various engines with a perfectly unbiased mind and I tried to understand what they were for. After refusing to sign the Peugeot contract, we said that we would take the Hispaño or none. They said we would take none. If the Hispaño had not also existed in Spain outside the lines of the war, we probably would not have gotten it at all. The history of the two engines was simple.

The Peugeot was built in a lot of less than 100 and washed out. The Hispaño was built to the extent of 45,000 by the end of the war and I think more Hispaños were installed in high-speed airplanes than any other high-speed airplane-engine.

> **The eight-cylinder V-type Cadillac and Hispaño engines are similar in design and weight, but the two types of design differ fundamentally because of widely divergent requirements.**
>
> **Weight is not detrimental in a motor-car where it is supported by the road, but is in an airplane which is supported in the air by engine power.**
>
> **Utmost care in manufacturing is necessary to secure accuracy and reliability. That an engine for commercial service should be designed very differently from one for military service is far from certain.**
>
> **For reasons of safety an aircraft engine should be operated with a large excess of power available the same as an automobile engine.**
>
> **Absolute gas-tightness is essential to successful operation for any length of time.**
>
> **More cylinders may be used if they can be mounted so as not to increase head resistance, but this will not lessen the cost. Aircraft engines cannot be built in the same quantities as motor-car engines at anything like the same cost per horsepower.**

Early Airplane Engines

At that time, and I think it is just as well to remind people of it, every type of engine we see today and a few we do not were in existence. The V-12 Rolls-Royce was just appearing in Paris for a test. Vertical air-cooled engines were in use in a number of forms. Fixed radial air-cooled engines were in use. The Salmson radial water-cooled engine, a very useful engine of its type, was in use and its history is interesting to those of us who wish to design an engine for a complete airship and not something to satisfy an airplane designer. This engine was washed out when I was there in 1915 by all the airplane designers as having too great head resistance. The Salmson Company, instead of being defeated by that, employed its own designer and in the following year succeeded in producing the most successful light bombing airplane that the French had. In other words, the dumbness of the airplane designers at that time and not any salient defect on the engine prevented it from being successful at the speeds that were then common in the air.

The Hispaño engine was the first of a very definite type, that is with the cast-aluminum cylinder construction with steel liners. That the designer of that engine foresaw its possibilities is a great tribute because it has never been improved on fundamentally for a liquid-cooled type since. The Napier Lion followed very shortly after and is still in very successful use today as a result of continuous improvement. The Curtiss B-12 engine, which is a highly successful engine, first appeared in about 1917 or the winter of 1917-1918 and has been developed up to the present time.

The air-cooled engines of those days usually had

[1] M.S.A.E.—Technical assistant to the president, General Motors Corp., New York City.

cast-iron cylinders or steel cylinders with fins. The adoption of aluminum cylinder-heads for air-cooled engines made the present-day radial air-cooled engine the success it is.

I have been practically out of the aircraft-engine business except as a spectator for eight years, but very often people who are on the outside see as much or more of the possibilities of what is going on than those who are much closer to the job, very often too close to the job. The airplane designer, if we talked with him today as I have in the last year, speaks the same language he did in 1917-1918. His remarks are all identical. We can wipe out the intervening 10 or 12 years and we would not know they ever existed. The engine is still almost powerless, has no reliability and is much too expensive, infinitely too expensive. The last comment is frequently based on the fact that we can buy a very good complete automobile for considerably less than almost any aviation engine except an OX.

Not being in the aircraft business myself, I think I can possibly be allowed to speak for that industry without being accused of favoritism in attempting to explain why motor-cars are so cheap, why aircraft engines are relatively so expensive and why with the materials that are available today for construction and for fuel they will continue that way.

A few years ago I stumbled on the fact that a remarkable similarity existed between the Cadillac eight-cylinder motor-car engine and the V-type 300-hp. Hispaño engine as is shown in Fig. 1. The latter was designed both abroad and here, but our design was somewhat different and fully as heavy or heavier. The difference in these two types of design is fundamental and because of the very differing requirements of the two types.

In reading Mr. Insley's paper[2] on the subject of aircraft-engine design as compared with motor-car engine-design, I began to think it over in relation to our present motor-cars and to the discussions we have as to what our program on motor-cars should be and why the public likes one car better than another. The fact is very, very clear that weight in a motor-car, far from being a disadvantage, is an actual advantage provided it can be obtained at low cost. I have asked a number of motor-car engineers which car would be the most salable in this Country, one weighing 4000 lb. or one weighing 3500 lb., if they cost the same and had the same relative performance on the road as to speed and acceleration and similar qualities.

They unanimously say that the 4000-lb. car would sell much better than the 3500-lb. car. I think they were absolutely right. The heavier car has a feeling of solidity and stability that the lighter one does not possess. The only doubt about it is the slightly increased cost of fuel and tires and the public is anxious and willing to pay that much to get what goes with it. The motor-car runs on the road, its weight is supported by the highway and the powerplant is not required to do that part of the job. As a result we have been able to build motor-cars from material of the lowest possible cost. It is better in a great many ways as to wearing qualities and such things, but it is also better from the fact that for quietness, smoothness and all other desirable qualities, rigidity is the item of greatest importance. Rigidity can be obtained only by heavy sections of material, heavily ribbed, unless we develop a material with a much higher modulus of elasticity than steel or cast iron. As a result we are actually seeing today motor-cars weighing 2500 or 2600 lb. sold to the public at a price of less than $600; the price per pound of those motor-cars delivered with the dealer's profit, cost of selling and all the other items is actually less than the cost of much of the material that is used in aviation engines.

Basic motor-car materials that constitute a large part of the weight run probably from 7 or 8 cents per lb. for complicated cylinder castings down to 3 or 4 cents per lb. or even less on steel parts. The only really very high-grade steel used in a motor-car is in some of the highly stressed shafts where actual elastic limit is highly important, and that is a very small part of the total weight of a motor-car.

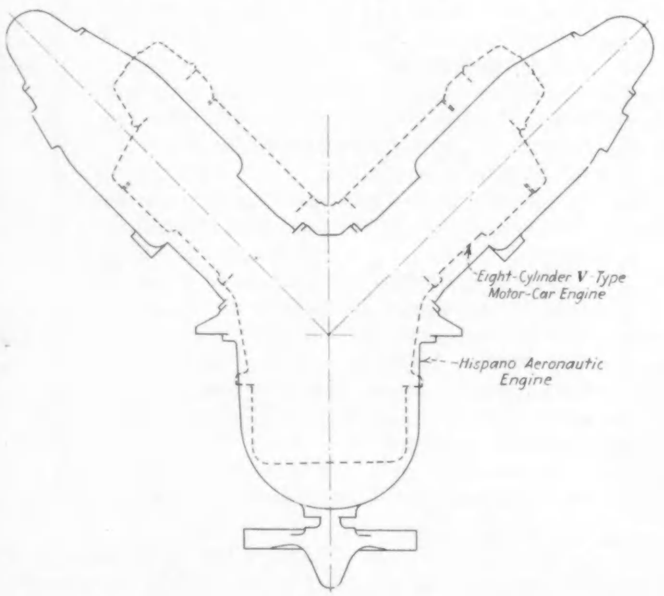


FIG. 1—SUPERPOSED END VIEWS OF THE EIGHT-CYLINDER V-TYPE CADILLAC MOTOR-CAR AND HISPAÑO AERONAUTIC ENGINES

The Similarity of the Two Designs Is Very Marked, Although They Differ Fundamentally Due to the Widely Divergent Service Requirements

Wherein Aviation and Motor-Car Engines Differ

The aviation engine is an entirely different proposition in every way. Supporting the airplane in the air is a matter of engine power primarily and nothing else. As a result, the cost of the airplane must be divided between the plane itself and the powerplant as in a motor-car but in an entirely different way. If we add a pound to the weight of an aviation engine, we must add some wing surface to carry it with its attendant weight. If we add 10 lb. it is just that much more. The whole structure becomes considerably more expensive or if we reverse the process we detract that much from the payload.

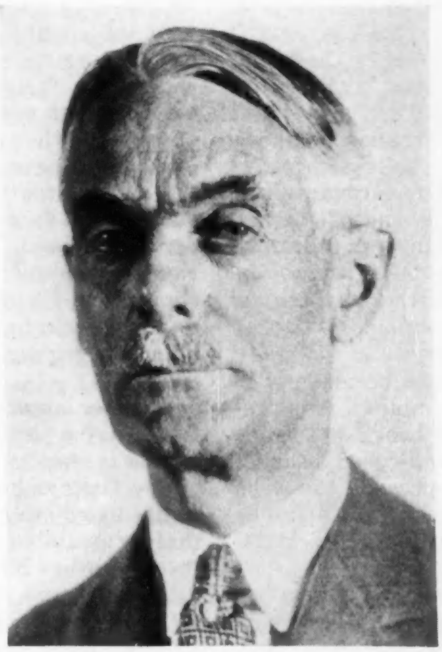
I have seen considerable comment on the extreme care used by the manufacturers of many aviation engines, especially the men who have been in the business the longest time. I think the temptation is to blame it on the Government and to say that the Pratt & Whitney Co. probably would not use the same care in manufacture if it were designing for commercial aviation. I have no way of proving that this in general is the only way to build aviation engines, but I am strongly

[2] See S.A.E. JOURNAL, August, 1930, p. 137.

inclined to suspect that it is true when the cost of operation enters into the consideration at all, coupled with the ability to do something really useful with the overall result, such as furnishing real transportation to the man who has the machine.

In aviation, more than any other industry, we discuss things called factors of safety, but a factor of safety really is a factor of guess or a factor used to cover variations from what is the accepted minimum. In cheaper forms of material, as in bridge structures, where the steel is static and stresses on it can be figured extremely closely, the designers talk freely of factors of safety of 5 or 6 or 7. All of that simply means that the job is made five or six times as heavy as it would probably have to be if they really knew exactly what they were making.

The old-line aviation-engine manufacturers are not inclined to build their product that way. They will actually reject connecting-rods that have scratches in them. The sad thing is that a scratch in the wrong place in the connecting-rod definitely reduces the life of that rod. A tool mark in the neck of the valve may cause a highly expensive wreck. I heard the other day of a wreck where a broken valve in one engine practically ditched the whole airplane. It caused a piece to fly off which went through the propeller, went across into the opposite engine's propeller and generally made a mess of the whole job. I do not know any way to prevent that except this close, high-grade inspection plus close, high-grade manufacturing plus inspection by the man who is actually doing the work.



H. M. Crane

Final Aviation-Engine Tests Impossible

In the Hispaño plant during the war an attempt was made to determine by final test what sort of an engine we had, which, of course, is absolutely impossible. A test that would prove anything about an aviation engine is so severe that a large part of the engine's life is taken in making the test and, even if the test is successful, we do not have anything when we get through.

On the 300-hp. Hispaño engine in Long Island City, we naturally had Government inspection. We were very willing to have it, but after the first six months of the war, we did not consider the Government inspection anything but a way of getting our money. My theory from the start has been that the manufacturer must know more about his engine and its possibilities than any Government inspector can possibly know and have a higher regard for its quality than the inspectors can possibly have.

We had a case in Long Island City where inspectors asked us to ship engines that our final-test expert inspectors said were not ready to ship. They pulled the horsepower with a good bit to spare. If we stood off at some distance, nothing apparently was wrong with them. The men who ran them, however, felt a peculiar shuddering that they recognized as a symptom of something that should not be. In every case when the engine was removed from the test stand for that reason, we found either a scorched cylinder or some other thing that needed rectification.

That type of manufacture is entirely different from the motor-car type of manufacture. I am in the motor-car business and I am at perfect liberty to tell you how the motor-car engine is built. It is built in varying degrees of quality by different manufacturers. Without any question the highest-grade manufacturing, when it comes to the quantity involved, is done by Buick. However, a Buick automobile, like every other automobile-manufacturer's product today, is delivered to the public without anything like a test of any kind to deliver its maximum possibilities. It is finally run in by the owner and brought up to power by the owner's cooperation and by cooperation with the dealer if it ever reaches its maximum power. Again, fortunately I think for safety on the highway, very few of our modern jobs ever reach anything like the maximum power they can be made to pull on a brake test by a trained engineer.

The safety element, of course, is involved in all of that. The less power the motor-car engine has, the safer the owner is, as long as he is satisfied with it and as long as he does not try to make too much speed down hill. The loss of power, however, in the aviation engine is likely to produce fatal results for the pilot or anybody else involved in the proceedings.

About two years ago I went with a party of engineers to the New Departure ball-bearing plant and I take the liberty of bringing this up because it has a very definite bearing on the production of engines such as aviation engines must be, I think, to produce the most economical results in the long run for the public. In saying that I want to avoid being taken as criticizing the present commercial-engine builders. One reason I left the aviation-engine business at the end of the war purposely was because at that time to design and build a really good aviation-engine and have the aircraft manufacturers buy it did not seem possible. We were bound to be in direct competition with apparently similar products, possibly rated in such a way that even our weight ratio would look inferior and with no real way of proving which was which. For that reason, I have the greatest sympathy today for the men in the aviation-engine industry who are selling engines for commercial purposes, because to make the really best job in the long run and at the same time satisfy the man who has to buy the engine is very hard.

0.0001 In. a Real Quantity

I was brought up to scoff at people who talked about 0.0001 in. People who have been around a shop feel that way; language like that is bandied around the shop. When I finished the day at the New Departure plant, I realized that 0.0001 in. was something that existed and was possible to control and that the method of control is solely due to the fact that operating in New En-

gland with a class of men as they do, they are able to eliminate inspection of the product almost entirely. The inspection at the New Departure plant is 90 per cent a tremendously rigid inspection of the tools, fixtures and measuring instruments, especially of the measuring instruments. As a result, the product is astounding.

To show the analogy between these two industries as a possibility of the aviation industry, a certain size bearing today can be put on the table alongside of one made five years ago and they look exactly alike. Even with a microscope I do not know that the difference could be told. Actually we can guarantee that the life of a bearing made today is from two and one-half to three times that of one made a few years ago and it is selling for a lower price. This is simply the result of a tremendous effort to overcome the little things that are not apparent on the surface and cannot be shown when the salesman takes a job around and shows it to the customer. For instance, the balls are forged from a rod; not just cut off. The rod is forged and an effort is made to draw the grain at the end of the ball into the smallest spot possible, because end-grained material is likely to wear faster than side grain. The races are forged so that the grain all the way around is as uniform as possible. The heat-treatment is watched in the same way and so on down the line.

As a result of that, a ball bearing can be made with such great accuracy today that, in assembling, it is preloaded. The preloading made the ball bearing feasible as a grinder device. It made the high-speed bearing operating under heavy loads feasible because the balls are always in contact with the races and always forced to roll at a continuous, constant speed instead of starting and stopping and thereby wearing away.

The same methods will have to be used with the aviation engine to produce what we all want to get. Some of our people in General Motors, when we began to cast an eye toward aviation again after having dropped it like a hot potato about six or eight years ago, assumed the old idea that the military engine was very "hot stuff" from a military point of view but, if we were building a commercial engine, it should be designed in an entirely different manner to produce higher reliability, primarily.

Rating Aircraft Engines Difficult

My opinion was, and I have not had a chance to prove whether I am right or wrong as yet, that we have nothing to indicate that we could build a much better 350-hp. engine for continuous duty over a long period by building it smaller and heavier than the Pratt & Whitney Wasp engine. That is something which history alone will tell. Unfortunately we will have a hard time finding out what are the real facts, because of the apparent difficulty of finding a way of rating an aircraft engine. You go everywhere today and people talk freely of 1800 hp. on 1500 lb. If one had not been in the industry as I have or as you men are, he would begin to get nervous and think possibly a whole new field that we had never heard of before was opening up to us and we would have to stop and look around and start all over again. We go a little farther and find that the 1800 hp. on 1500 lb. is possibly available for 3 hr., after which the engine is scrapped or a large number of the parts are scrapped and replaced by new ones. Obviously that is not an 1800-hp. engine from anything like the angle on which any of the present standard engines are rated.

Equally, the horsepower of any of the standard engines is bound to be based on some life at full throttle What that is, we do not know. We do know that for safety reasons the aircraft engine should be run much as the motor-car engine is, and that is to have a very great excess power available. Kettering's attitude, in the main, is that the powerplant of an aircraft should be capable of delivering almost twice the actual cruising horsepower at sea level, if we want a thoroughly safe job. On that basis, of course, the over-all life of the engine is run at a very much smaller horsepower than the rated horsepower, and the life becomes very much longer in consequence. We really do not know today how we should go at that problem if we had a free hand, if we were designing an over-all job to carry passengers or freight at the lowest possible cost, because we have not got enough data to work on, in the construction either of the airplane or of the engine.

During the war the Liberty engine was supposedly rated at approximately 420 hp. As then built it actually was not really a reliable engine at even 350 hp. over a period of time. It is today, or has been within a short time, a very successful commercial engine based on two changes in its operation. One was the eradication of minor defects in certain things that cropped up and the other in running continuously at a more reasonable power.

Another angle between the motor-car and the aviation engine is its emergency rating. A motor-car engine is obviously run at half or third power for much of the time and only on some occasion when the driver wants to go very fast does he try to use the full power that is available. If he is three or four miles short in speed of what he might do, it makes no difference. On the other hand, if a multi-engined airplane gets in a position where one engine goes dead and it is pretty heavily loaded, we have a real reason to use the maximum power of the other engines. We do not know in what condition those engines will be to deliver their maximum horsepower after months of use at reduced horsepower. Everyone who has operated aviation or motor-car engines knows that the fundamental of successful operation for any length of time is practically absolute gas-tightness. If any considerable leakage of gas past the piston occurs, an inevitable overheating and drying up of oil on the surface follows, with an accumulated effect that will practically wreck an engine in a very short time. The very large cylinder air-cooled engines are bound to change their shape more or less under the temperature difference caused by difference in operation or even difference of speeds through the air. Just what does happen to those engines when the emergency comes is a question and has a very serious effect on the rating. What may result will be to go to even more cylinders if we find a way of doing so and mounting them in the airplane in such a way that we do not seriously affect the performance of the airplane due to bad head-resistance or otherwise. Certainly increasing the number of cylinders will not be a method of lowering the cost.

As we go from one extreme to the other in the possibilities of aircraft-engine design, no chance whatever of building the aircraft engine in the same quantities at anything like the cost per horsepower of the motor-car engine is apparent. This includes the fact that the motor-car engine has a much higher degree of silence and smoothness than the aircraft engine does so far. It will inevitably be built of much more

expensive materials and, due to requirements of reliability and otherwise, the materials must be machined at a far higher cost, inspected much more closely and tested much more thoroughly, which does not mean only a final test. No final test is a possible measure of what we really have. We never know how near a part is to breakage until it is broken, and then has told us how close we were to serious trouble.

Present Aviation Courses Wrong

One of the unfortunate things of the aviation industry is the amount of mystery that has been developed around the flying part of the business, as against the actual source of power. This has tended to result, certainly in most educational institutions, in the aviation courses being courses in aerodynamics and wind-tunnel work and strength of structures along the type of bridge design. We have had the same thing in the motor-car business, a tendency to specialize in the rear-axle men and steering-gear men. That never produces a thoroughly good motor-car. The best motor-cars are the result of a master mind that develops an all-round compromise between all of the factors involved. The close cooperation that is now beginning between certain airplane and engine manufacturers will undoubtedly go a long way toward improving this condition, but unfortunately the primary education of the men who design the airplanes has been all wrong uptodate in every institution of learning that I know anything about. I have tried to get Dr. Stratton of the Massachusetts Institute of Technology to consider putting an engine man in charge of the aeronautic course just as an experiment, because I think it will be very interesting and the chances are that it might be very successful if he put a broad-minded engine man on the job. The engine is fundamentally *the* airplane today just as much as the time that Wright flew his first machine. Those who know Wright best will tell us that the aeronautic efficiency of the early Wright machines and their ability to lift weight with a given horsepower were fully equal to the capabilities of the present machine. Streamlining had not been carried to any great extent, but on the other hand Wright could land one of those machines in a small space. To build one very much along those lines and exhibit at one of the air meets would be rather amusing and would let the public see what they really could do with a good powerplant. We could probably fly one with a Cirrus engine or something of similar design and, when it came to landing, it would make even the Autogiro look rather not so much.

The most important thing about getting the airplane itself designed from a powerplant point of view is the installation of the engine. I never have taken much stock in the glider, at least in a certain way, and I never believed the glider would be at all popular with airplane designers. The airplane designer without a powerplant to blame for the deficiency of his own work just could not exist.

During the war we ran several thousand of the Hispaño engines on the final test, which was approximately 4 hr. at 150 hp. It was a green engine, built in a plant hurriedly gotten into production, but the number of those engines that stopped during that 4-hr. test due to anything happening in the engine itself was practically negligible. The same holds true today and is partly due to two things. The engine is not designed in the best possible way for the airplane and, even more, the plane is a hurried design to meet some particular whim of the occasion or the demand of some operator who really does not know what he could possibly get. The engine is put on the airplane, coupled up in the quickest possible way with the various oil and gasoline pipes and other controls and the job is put out and flown. That a job of this kind should give considerable trouble in the field is inevitable. Such an airplane is bound to be expensive to maintain and we are only lucky if we do not have serious accidents with it.

Engine Mounting Important

Whether an engine is a smooth job or not will be determined in the long run by how it is mounted and the general structural characteristics of the airplane. We have that identical problem in motor-car design. Recently I rode in a sample of the 12-cylinder Cadillac that was announced a little while ago and is not yet in production. A month or so ago I rode in an eight-cylinder Cadillac chassis with the same powerplant. They were not like the same automobile in many respects, mostly acoustic in this case, although I noticed symptoms of vibration that apparently were due to muffler vibration but might not be for they could be anything else. As a result, months of hard work are required to eliminate those defects and to realize the smoothness that is in the powerplant itself.

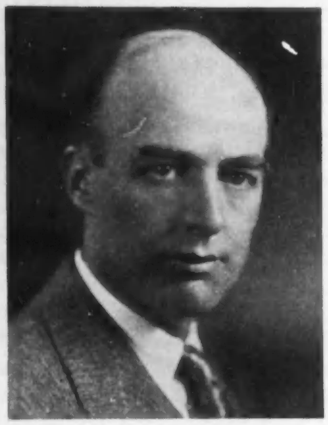
That is inevitably true in design of an airplane and also appears in motorboat design. One company in New York has specialized in the design of these large twin-screw Diesel-engine yachts to a great extent. It employs one of the very best engineers it can get as an expert on mounting the engine in the yacht and the speed at which to run the engines, the propeller design, the engine beds, on tying the engines together and everything that goes with it. As a result, almost identical yachts of about three or four years apart in time of construction, with engines of almost the same design, are completely different in the over-all characteristics as to apparent engine-feel. As a step farther than that, Kettering has experimented in his own boat with a synchronizing arrangement that consists in tying the two engines together electrically as if they had one crankshaft and producing a single multi-cylinder effect with twin screws. We again get a surprising increase in smoothness by this combination which he predicted as inevitable and, much to the surprise of people who build engines and those who build yachts. This must be taken into consideration in making a thoroughly reliable, smooth-running airplane.

Where these relationships between the two industries do end is almost impossible to say. I do not think they ever end. The two problems are almost identical if we take into consideration the fact that in one case the load has to be supported directly by engine power and in the other case it has not.

In concluding, I want to remind you again of the important fundamental that I stated earlier as to the relative cost of the two jobs being due to the fundamental desirability of weight in the motor-car and the fundamental desirability of lack of weight in the airplane and its engine which results in the use of low-cost material in the motor-car and high-cost material in the aircraft engine. The inevitable result of that, of course, is a much higher-priced product per pound or per horsepower, even when built in comparable quantities.

THE DISCUSSION

CHAIRMAN J. H. GEISSE[3]—The Gisholt Company during the war took a contract to build cannon. One particular part, the breechlock, had to be practically hand machined. The best tool makers were put on that job and failed one right after another. Some girls who had never been in a machine shop were put on the job, and the first girl turned one out. After that I think the percentage of rejections was somewhere around 5 per cent with inexperienced girls operating these machines.



J. H. GEISSE

Mr. Crane mentioned that much of the vibration of an engine may be charged to the mounting. The Comet is rough, but it is not any rougher than any other radial engine, for they are all rough. I was told that one particular airplane was too rough to fly. We had received the same complaint on this type airplane at other times. By a simple change in the mounting the engine was made just as smooth as any other.

Carburetion and Ignition Systems Unsatisfactory

WESLEY L. SMITH[4]:—We have found that the carburetion system now in use on airplane engines is not entirely satisfactory for aviation purposes. Carbureters that are subject to acceleration in turbulent air, such as those on aviation engines, which has no counterpart on the ground, simply will not work satisfactorily. We are having fuel consumptions that vary from 30 to 50 gal. per hr. in 500-hp. aviation engines. Those variations, as near as we can determine, are caused simply by atmospheric conditions, not only acceleration and gravity affecting these but also the vast changes in moisture content and temperature of the air through which our airplanes fly. These conditions cannot possibly be encountered on the ground. Our airplanes do considerable flying up through the clouds where the moisture is more than can exist on the ground. Under those conditions the carburetion at present is not efficient. We have done the best we could. If the airplanes are to survive, the present carburetion system on engines must be redesigned. Those things are now coming to light as we are learning to fly through all of the weather conditions that are encountered. Not very many airplanes are now flown through all of these weather conditions. We are trying to do it, and I think we are about as successful as anyone.

The present ignition system is not satisfactory under all of the moisture conditions that we meet in the air. We are having radio installed on all of our airplanes, which complicates matters somewhat. The ignition system as we have it now will have to be redesigned not only to meet the moisture conditions but also the shielding condition required by radio. The effects introduced are much larger than any engineers seem to realize at present.

I am making these observations just to point out that we are moving forward, and as we do, we run into those problems and conditions that we did not know existed before. The same thing happens in every other form of transportation. Mr. Crane pointed out that in the automotive industry they encountered problems that they did not know existed. We are encountering problems in aviation that are really serious.

One thing he did not mention for which we have great hopes is that the fuel-injection system which is now being applied to the airplane engine may solve some of the difficulties by eliminating the carburetion. It looks like a good possibility from two angles, one to get rid of carburetion and the other to get rid of starters. If we can inject the fuel directly into the cylinders and then fire it, we probably can eliminate all of the electrical starters, none of which are very satisfactory.

JOHN D. AKERMAN[5]:—I want to thank Mr. Crane for the frank statement about aviation having too much mystery surrounding it. I think part of this mystery is attributable to the mystery surrounding the engine. For example, when salesmen come around to sell a powerplant, each of them has some mysterious quality in his engine which is supposed to make his product superior to others. This mystery surrounding the airplane tends to kill the interest and confidence of the public; likewise, the more mystery that surrounds the engine the less confidence is displayed on the part of the public, who obviously will ask, "What happens to the airplane when the engine stops?" The airplane engineer is the one who has to find a simple non-mysterious solution for the whole problem. I wonder how Mr. Crane's suggestion to have an engine man in charge of an institution devoted to the development of aircraft would improve the situation. Regardless of how good engines are, they are apt to stop occasionally. At the point where the engine stops, the aircraft designer's job is to carry on. The designer is responsible for the whole problem, consequently the mystery surrounding the engine is a great handicap to him.

WESLEY L. SMITH

CHAIRMAN GEISSE:—The only two big mysteries about engines that I know of are what the airplane manufacturer wants and how we can possibly build engines, sell them at the price he wants to pay for them and still make money.

Care in Manufacturing Essential

H. M. CRANE:—I am sorry that the Chairman misunderstood my point of view on the question of work-

[3] M.S.A.E.—Vice-president in charge of engineering, Comet Engine Corp., Madison, Wis.

[4] A.S.A.E.—Chief engineer, National Air-Transport, Inc., Chicago.

[5] Professor of aeronautics and acting head of the department of aeronautical engineering, University of Minnesota, Minneapolis, Minn.

manship. I do not favor the use of high-grade tool makers in building aviation engines any more than building anything else. What he got probably when he took tool makers off and put girls on the job was conscientious work instead of a lackadaisical, don't-care kind of work. That is what I am talking about, the eye on the job and not looking out the window, and all that, the eternal vigilance that prevents things coming different from the tool set-up and with a different kind of finish than you are supposed to have, I mean with scratches where scratches should not be and all that sort of thing. That is just as likely to be obtained by girls who are physcially able to do the work as with high-grade tool makers. Unfortunately the airplane industry does not justify the kind of tools that the automobile industry has been able to buy for making motor-cars. What those tools can do is almost beyond belief. Yet to go through an automobile plant and find that the greatest improvement that has been made in the last 10 or 15 years is in handling material, and in reducing the physical labor of lifting this, that and the other part onto a tool and clamping it down is very interesting. That is just as easily applied to aircraft production as the other, with a little thought.

In addition I want to say in 1915 the Hispaño engine was being built in the Hispaño works in Paris in lots of three or four a day. Birkiat, who designed the engine, had more production imagination than almost anyone in this Country. He designed a set of fixtures that he could put on the simplest kind of tools to build that engine, and they were building it mostly with the help of boys. This was when France was up to her neck in the war and getting men was hard. About the only really high-grade men that they had in the plant at that time were the foremen.

JOHN D. AKERMAN

I do say that no substitute is available in aviation-engine work for conscientious attention of the person who is taking the cut or doing the operation. No subsequent inspection will correct for a lapse after the job has been done. But by thoughtful tooling-up and a proper attitute of mind toward the finished product, we can get a high-grade product at as little cost as is possible with a thing that is as technical as an aviation engine still is and will be for a long time, in my opinion, if it is to be really good. The difference in our shop was that when we started building aviation engines with a superintendent who did not believe in the game we never had enough material in the assembly department to put the proper number together, and under those conditions more machine-tools would be installed and more parts made so that enough would be available. That superintendent fortunately got sick in the summer of 1918 and was replaced by the assistant. He developed the bright idea that perhaps, if the machinists did not spoil so many parts, the assembly department would have plenty, and he promptly proceeded to carry it out. Not only did that produce much cheaper engines but the engines for the first time were really some good. The shop, instead of being a down-and-out organization, suddenly developed a belief in the product and a desire to see it develop.

That is the hard thing that the engine people are going through at present, establishing a kind of reputation that Buick has and that Ford has. One is in my company and the other is outside, so I couple them together. They have a reputation that takes the public right to them, because of their personality proved over a period of time. If any mystery exists in the aviation industry today, it is the human mystery of which plant means to do a good job and of which manufacturer is trying to make money out of what he calls engines. Time alone will prove it.

The company that has the conscience coupled with a reasonable degree of intelligence will win more in this game than any other, because errors come home to roost in the aviation business that do not in the automobile industry.

Symposium on Aircraft Fuels

(*Concluded from p.* 708)

bureter, but of a semi-hard jet-black sooty nature in the combustion-chamber and around the tops of the cylinders. The carbon deposit found on the valves at times seemed to be a hydrocarbon deposit from an excess of oil rather than any deposit from the wax ingredient. It was found to a decidedly less extent when a very heavy deposit of wax was in the fuel tank and to a greater extent when a very thin lubricating oil was used in the crankcase, as this oil was continually being pumped from the crankcase up into the cylinders and burned. When heavy lubricating oils that did not readily yield themselves to this pumping action were used, little or no carbon formed on the valves, and during this time the heavy deposits of carbon gradually disappeared. Also, at this latter time, some of the heaviest deposits of the gum were formed on the sides of the combustion-chamber.

Another reason why I would separate the formations into two classes is that tests made at several times showed that the wax and the sooty formation on the walls of the combustion-chamber had a foundation of sulphur or a sulphur derivative. Especially was this proved to be the case with the gum in the gasoline tank and carbureter, as minute particles of sulphur could be obtained from the gum deposits in the former. This caused me to decide that the gum was a form of amorphous sulphur held in suspension in the gasoline ordinarily but deposited under favorable conditions.

Standardization Progress

Rating Fuels for Detonation

Further Progress by Lubricants Division Toward Adopting S.A.E. Recommended Practice

FURTHER study by the Methods of Measuring Detonation Subcommittee of the Cooperative Fuel Research Steering Committee and the Lubricants Division of the S.A.E. Standards Committee, since the report of these committees was published on p. 241 of the August, 1930, issue of the S.A.E. JOURNAL, has resulted in revision of the proposed Method of Rating, to the following:

Gasoline knock-testing results shall be referred back to heptane-octane by using a scale of octane numbers, the octane numbers to be the percentage of iso-octane (2, 2, 4, trimethyl pentane) by volume, in a mixture of iso-octane and normal heptane required to match the antiknock value of any given fuel.

This revised proposal was referred to the Lubricants Division early in October following a meeting of the Subcommittee on Measuring Detonation that was held on Sept. 15 in New York City, at which the definition of octane number was changed. The revision was also approved at that time by the Cooperative Fuel Research Steering Committee.

The revised recommendation of the Subcommittee differs from that made on May 28, 1930, only in the definition of the term "octane number." The fundamental principle of referring knock ratings to mixtures of pure hydrocarbons is unchanged and the same two hydrocarbons (heptane and iso-octane) are recommended.

Reason for Redefining Octane Number

The chief reason for defining octane number as "percentage of octane in blends of heptane and octane" rather than as "parts of octane added to 10 parts of heptane" may be summarized as follows:

While either definition results in a satisfactory scale for motor fuels of today, which range in antiknock value from about 50 to 80 per cent octane, it appears probable that future developments may result in fuels approaching pure octane in antiknock value, or even exceeding it. If the octane number were defined as originally proposed, fuels equivalent to 95 per cent octane or more would have numbers which would appear entirely out of keeping with their actual antiknock value, as the "parts of octane per 10 parts of heptane" approaches infinity as one approaches pure octane. This objection does not hold if the octane number is defined as "percentage of octane." Pure octane would have an octane number of 100 and the scale could be extended above this point by such a secondary definition as "octane numbers above 100 are defined as 100 plus the percentage of pure benzene in iso-octane-benzene blends." Whereas this may be considered as looking too far into the future, it is felt that any scale to be adopted should be capable of indefinite extension without abandoning the scale used for fuels of today.

The Lubricants Division, at its meeting in Chicago on Nov. 12, at which members of the Subcommittee on Methods of Measuring Detonation were present, confirmed the letter-ballot of the Division members approving the recommendation for submission to the Society for adoption as S.A.E. Recommended Practice at the Annual Meeting to be held in Detroit in January.

Tractor-Trailer Connections

Chicago Meeting of Subdivision Makes Progress Toward Desired Standardization

THE Subdivision of the Motorcoach and Motor-Truck Division of the Standards Committee that was appointed at the joint committee meeting during the Transportation Meeting of the Society in Pittsburgh in October, as referred to on p. 614 of the November issue of THE JOURNAL, held a scheduled meeting in Chicago on Nov. 13, at which definite progress was made. The increasing importance of having adequate interchangeability between different makes of semi-trailer and trailer connections was emphasized, particularly from the truck operators' viewpoint.

At the Chicago meeting the Subdivision decided to develop first a four-wheel-trailer eye and pintle connection, the standard to apply to the eye so as to leave each trailer manufacturer free to design his own type of pintle that will be interchangeable in the standard eye. It was suggested that the eye be made of 1¼-in. round-section stock with the opening 2¾-in. in diameter, and that a minimum drawbar pull of 80,000 lb. be provided for

The Subdivision will give further study to the most desirable method of securing interchangeability of semi-trailer fifth-wheel connections, which method, if embodied in a dimensional standard should govern the size of the pin and specify its location, in the upper or lower section of the fifth wheel.

Future recommendations of the Subdivision on the foregoing types of connection will be circulated among the vehicle manufacturers and the operators for their criticism or approval before a final standard is adopted by the Society in order to assure that whatever standards are adopted will be entirely acceptable to all branches of the industry that will be affected.

Members of the Subdivision, all of whom attended the meeting in Chicago, are Paul P. Pierce, Vacuum Oil Co., chairman; G. W. Chamberlain, Fruehauf Trailer Co.; D. H. Davis, Highway Trailer Co.; M. C. Horine, International Motor Co.; R. B. Jones, Lapeer Trailer Corp.; L. V. Newton, Byllesby Engineering & Management Corp.; Pierre Schon, General Motors Truck Co. (represented at the meeting by J. P. McArdle).

PAUL P. PIERCE
Refined Oil Department, Vacuum Oil Co.; Chairman of Subdivision on Tractor-Trailer Connections

Motorboat Division Meeting

AT THE OCT. 21 meeting of members of the Motorboat and Marine-Engine Division in New York City, progress was made toward standardization that, when completed, should be of very material value to motorboat and motorboat-engine manufacturers as well as the users of motorcraft. As

(*Concluded on p. 719*)

Production Engineering

Seen in Detroit Shops

Machinery and Equipment in Plymouth Plant and Chevrolet Forge-Shop

MUCH interesting machinery and equipment was observed at the plant of the Plymouth Motor Corp. and the forge and spring shops of the Chevrolet Motor Co. by the Production-Meeting guests who made the plant visits for which arrangements had been made in connection with the meeting. A few photographs from these plants were shown in the S.A.E. JOURNAL for November, in connection with the story of the Production Meeting. Others will be given herewith.

One of the most interesting machines seen in the Plymouth plant was an automatic piston-turner, seen in Fig. 1. Two of these are at work in the factory, and they are said to be the only ones of the sort in existence. These machines seize the rough pistons, put them in place in the machine, turn the outside diameter, cut the three ring grooves and partly turn the head, all in one operation.

Another unusual automatic machine, shown in Fig. 2, was seen at work on starter pedals, doing milling and drilling operations simultaneously on the same machine. Eight radial holes are drilled at once in the brake-linings and brake-shoes by the special machine shown in Fig. 3.

While great advances have been made in machine-tools for automotive plants, handling equipment and machines for other purposes than removing metal have undergone even greater development. Fig. 4 shows the washer at the end of the machine line in the rear-axle-housing depart-

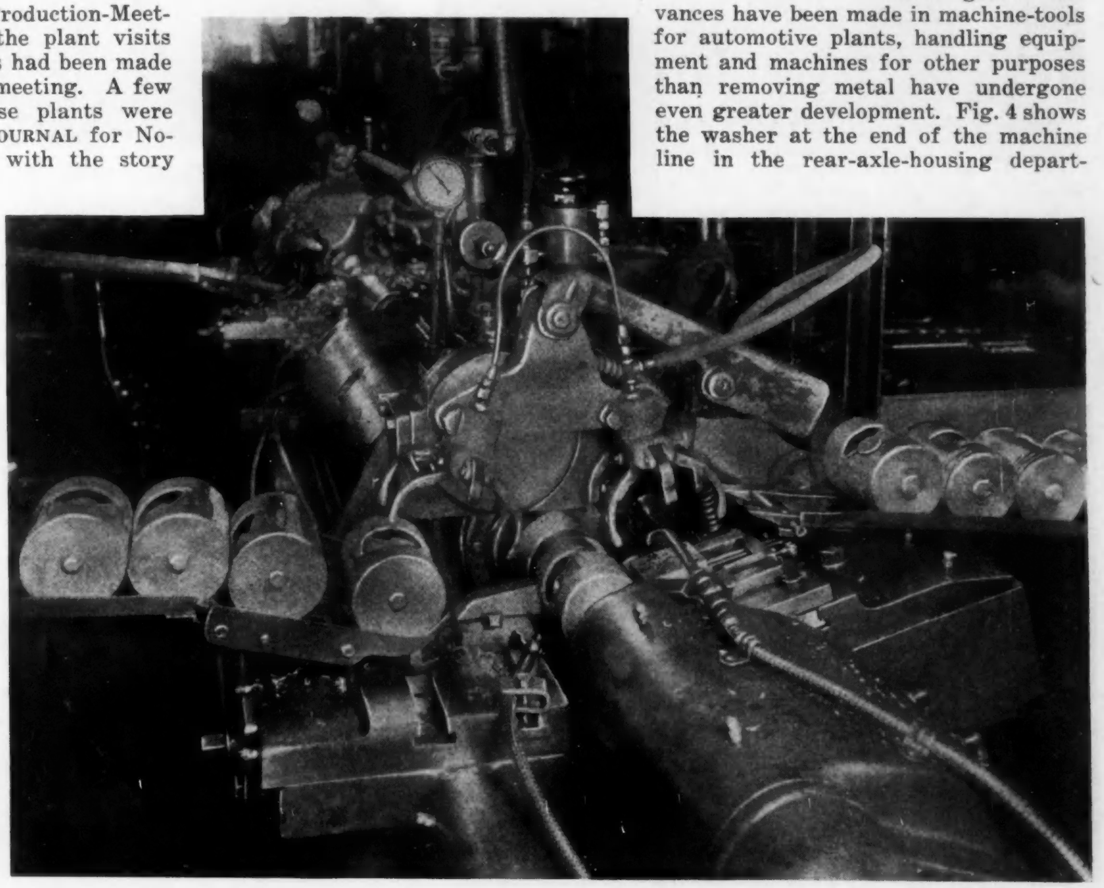


FIG. 1—AUTOMATIC MACHINE FOR TURNING PISTONS IN PLYMOUTH PLANT

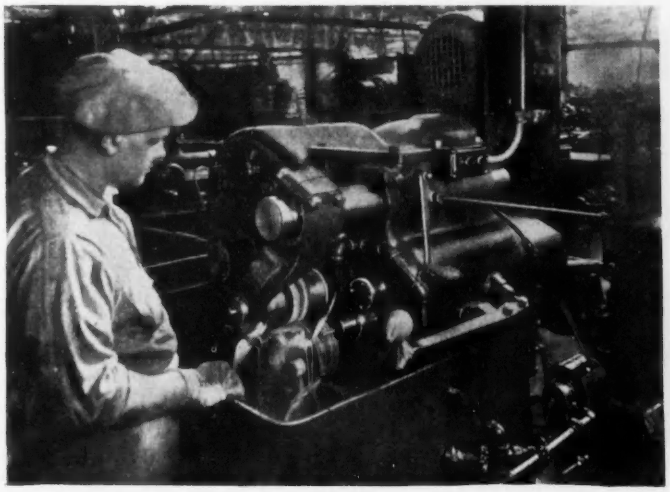


FIG. 2—MILL-DRILLMATIC MACHINING STARTER PEDAL

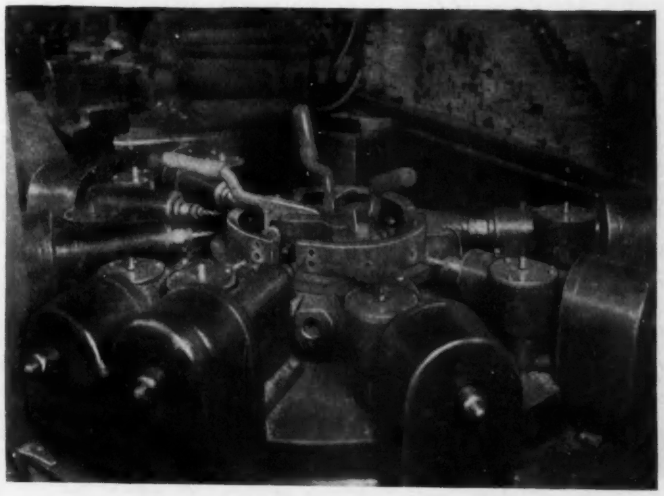


FIG. 3—DRILLING PLYMOUTH BRAKE-BANDS AND SHOES

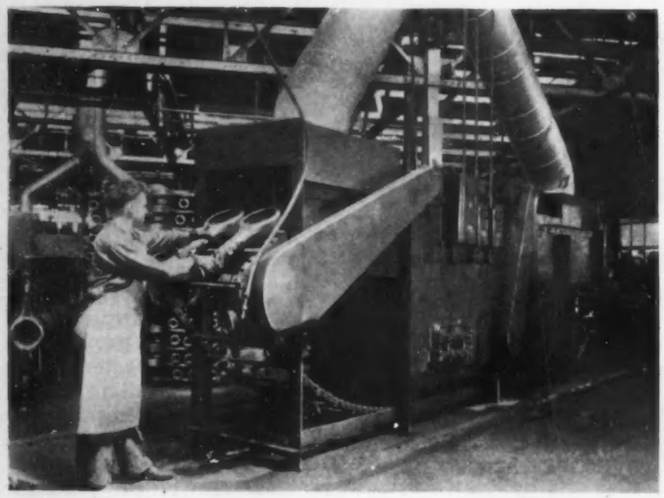


FIG. 4—AUTOMATIC MACHINE WASHING AXLE-HOUSINGS

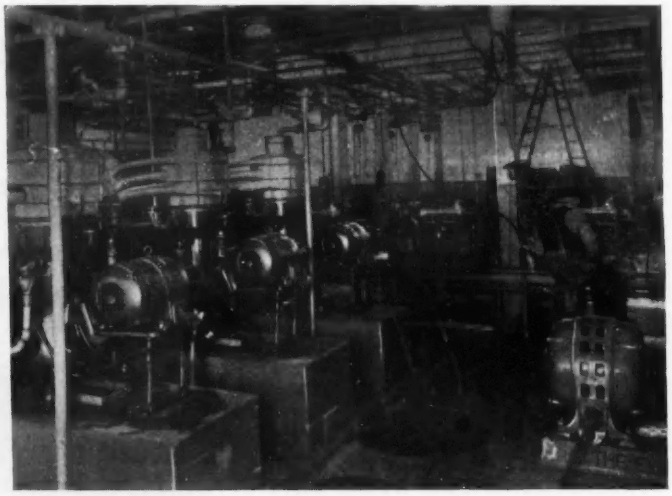


FIG. 5—CENTRIFUGAL CLARIFIERS FOR CRANKCASE OIL

ment of the Plymouth plant, in which the housings are thoroughly washed in soda solution and dried automatically. The chain conveyor which carries the axles through the machine is provided with cradles to locate the housing definitely.

Plymouth engines are assembled in an inverted position until the oil-pan has been put into place. Each engine is given a 2-hr. run-in, using illuminating gas for fuel. The electrical current for ignition is furnished by a central ignition plant, and the oil and water used are in constant circulation. Centrifugal oil clarifiers used in connection with this work are shown in Fig. 5. After the run-in, each en-

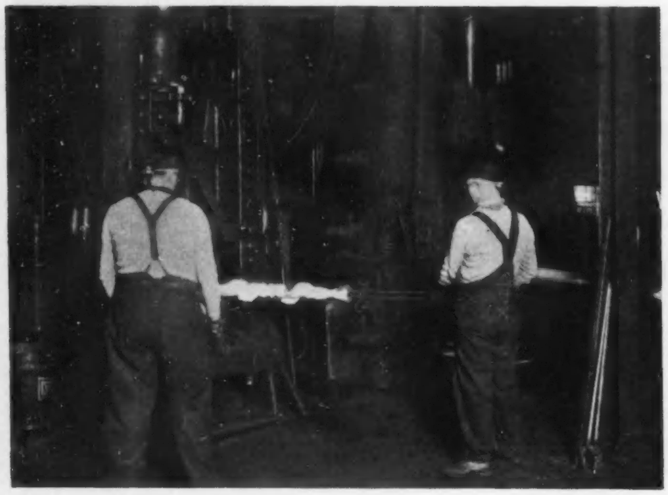


FIG. 6—FORGING A CHEVROLET CRANKSHAFT

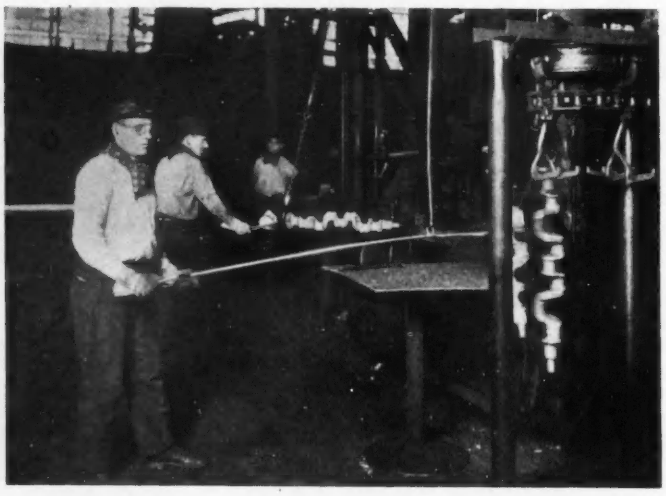


FIG. 7—LOADING A FINISHED FORGING ON THE CONVEYOR

FIG. 8—UNLOADING CONVEYOR AT HEAT-TREATING FURNACES

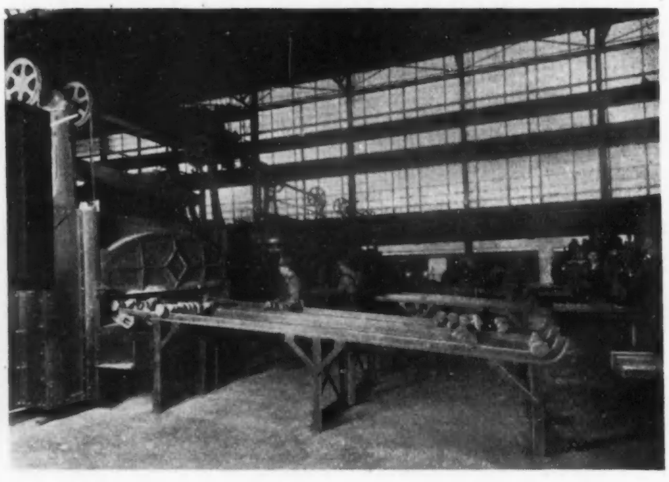


FIG. 9—DISCHARGING END OF ANNEALING FURNACES

FIG. 10—HANGING THE FLASH ON THE SCRAP CONVEYOR IN CHEVROLET FORGE-SHOP

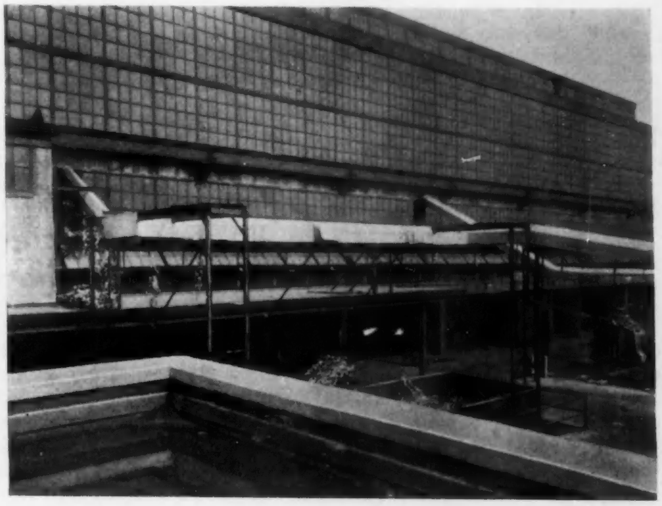


FIG. 11—DISCHARGING END OF SCRAP CONVEYOR OUTSIDE THE BUILDING

gine is given a dynamometer test, during which it must show normal horsepower on gasoline fed through its own carbureter.

Chain conveyors and other mechanical aids to handling are much in evidence in the shop in which Chevrolet crankshafts are forged. The hammer-man seizes the square billet in the furnace with tongs that are supported by an adjustable chain or cable from a light overhead trolley. With the aid of this support, he carries the billet to the steam hammer, and similar trolleys are provided for transferring the partially forged shaft from one hammer to the next, as seen in Fig. 6, and for loading the finished forging on to the overhead chain conveyor shown in Fig. 7, which carries it to the heat-treating furnaces. The double-forked tools with which the crankshafts are removed from the chain trolley, as illustrated in Fig. 8, are provided with a similar support.

Crankshafts are propelled through the heat-treating furnaces by pusher-bars, and mechanical arms plunge them into the quenching bath and remove them between the heat-treating furnace and the annealing furnace. Crankshafts are seen emerging from the annealing furnace in Fig. 9.

Scrap also is handled by a chain conveyor having alternate hooks and platforms suspended from it. Flash trimmed from the forgings is hung on the hooks, and the ends by which the crankshafts are held in the hammers are cut off and placed on the platforms. The loading of these trimmings on the conveyors is shown in Fig. 10. Incidentally, this end is not consigned to scrap, but is used as material for one of the gears in the transmission and therefore is discharged from the conveyor at one point, while the flash is discharged at another point where it is conveniently loaded into gondola cars. The discharge end of the conveyor, outside the building, is visible in Fig. 11.

Standardization Progress

(*Concluded from p.* 716)

rapidly as these projects can be shaped into definite form, they will be circulated broadly to the motorboat and engine industry for study and constructive criticism.

Outboard Engines

Desirable standardization for outboard engines has been considered recently both by the members of the Division and the Outboard Motor Manufacturers Association, relating principally to the mounting dimensions for this type of engine and propeller shaft-ends. A Subdivision consisting of W. R. Beckman, of the Johnson Motor Co., and F. T. Irgens, of the Outboard Motors Corp., was appointed to draft a definite report on outboard-engine mountings and to prepare a list of other outboard-engine subjects for standards.

In 1918 the Society originally adopted the tachometer drive for aircraft engines, the engine end of the driving shaft of which was 0.152 in. in diameter. Because of breakages of the shaft, this diameter was increased to 0.187 in. in 1922 and remained standard until 1928, when, largely because of improved materials being used, the diameter was reduced to the original 5/32-in. shaft. In the meantime, however, the 3/16-in. diameter shaft had come into use by the motorboat industry for fuel-pump as well as tachometer drives.

After considerable study of the matter, those present at the Division meeting voted to recommend adoption of a motorboat tachometer drive having a 3/16-in. shaft and that only the engine end of the drive be adopted. All other dimensions would be virtually the same as the present S.A.E. Standard for aeronautic tachometer drives, p. 14 of the 1930 edition of the S.A.E. HANDBOOK. The Division also discussed the desirability of having a standard reduction-drive ratio, but this was left for further study, with the suggestion that the ratio for engines operating at not over 2000 r.p.m. be at engine speed and for engines intended to operate above 2000 r.p.m., at half engine-speed.

Propeller-Shaft Couplings

When the present S.A.E. Recommended Practice, p. 413 of the 1930 edition of the HANDBOOK, was formulated in February, 1929, it was intended that the couplings should be made of high-strength material and definite S.A.E. steels were proposed but the Standards Committee, in approving the report, deleted the steel specifications. The question of material has again been considered by the Division because of lack of complete information in the standard regarding its applicability, and the Division has now recommended that the following note be included under general information given on the HANDBOOK page referred to.

Material.—The design of these couplings requires that they be made of a suitable grade of steel or similar high-strength material, as cast iron is unsuitable for couplings of this type and these dimensions.

Transportation Engineering

Highways and Vehicle Taxes

Prof. W. E. Lay[1] States Outlook Following Sixth International Road Congress[2]

VIEWING in perspective the Road Congress held in the City of Washington, Oct. 6 to 11, 1930—a convention of momentous importance to world economic progress—Professor Lay and Professor Morrison agree, according to a recent letter received from the former, that the actual benefit of the Congress to the United States from a technical viewpoint may be rather slight, although it seems quite probable that the United States will derive considerable benefit diplomatically. Professor Lay's opinion is that the South American countries look with especial favor upon the United States' highway engineers as leaders and are eager to use the ideas, methods, and plans of organization that these engineers have worked out.

Taxation of Motor-Vehicles

Professor Lay states that he was especially interested in the discussion relating to motor-vehicle taxes at the Congress. He remarks that the United States has taken the attitude that all motor-vehicle taxes should be used for upkeep and for building new roads. He adds that these taxes have been quite reasonable.

Some countries have taken the viewpoint that motor-vehicles could be taxed heavily because of their being in a measure popular playthings; and that perhaps they could be taxed beyond the needs of a given road-building program. Further, that less than one-half of the taxes derived from motor-vehicles be applied to the building of roads. Only France reached the figure indicated. He believes that delegates of these countries were nominally opposing the passing of such a resolution because of the stand their governments have taken, but that they were undoubtedly pleased that the Congress passed the measure unanimously against their slight opposition because they can use the resulting resolution to influence their governments.

One of the delegates from a certain nation called attention to the fact that the gasoline tax is a very excellent measure, and that only those vehicles actually operating on the road would pay the tax. But, in fact, the effect of a gasoline tax goes much further than that.

A Previous Debate Cited

In a debate[3] on the gasoline-tax measure in Michigan, in which Professor Lay participated several years ago, he assembled enough operating data to be enabled to draw a curve of fuel consumption in terms of miles per gallon versus speed, Fig. 1; and in terms of miles per gallon versus gross weight of the vehicle, as shown in Fig. 2. In this manner he determined that, the heavier the vehicle is, the less is the distance which it will travel per gallon of fuel. The heavy vehicles have a more destructive effect on roads than do the lighter ones, especially on gravel roads. He also found that the high-speed vehicles use about twice as much fuel at 60 m.p.h. as they do at 20 m.p.h, and that they cause a great deal more damage to the road at high speeds than they do at low speeds. In his opinion, the tax on gasoline takes care of these two types of variation, at least in some measure.

Assuming that a tax is placed on gasoline, Professor Lay says in the debate mentioned that the fuel consumed is more or less a measure of the distance traveled by a vehicle over a road system and the tax is proportional to the distance traveled. The tourist who travels in Michigan will on the average buy fuel and be taxed in proportion to the distance he travels over the highway system of that State.

The curves in Fig. 1 show the characteristic relation between the speed and the fuel mileage of a motor-vehicle. The car will travel 19 miles per gal. at 25 m.p.h., but only 14 miles per gal. at double that speed. In other words, if this car is driven over a road 100 miles long at a speed of 25 m.p.h., it will use somewhat more than 5 gal. of fuel. But if driven at 50 m.p.h., it will need over 7 gal. of fuel. Hence, a greater tax will be paid by the vehicle traveling at a higher speed and consequently doing greater damage to the road.

Joint Fuel-Consumption Study Begun

About 1922, the petroleum and the automotive industries undertook a joint study of the fuel consumption of the automobile under actual-service conditions. Some 60 cars were used in both winter and summer tests on four different types of petroleum fuels. The circles in Fig. 2 represent the average fuel-mileage plotted against the gross

[1] M.S.A.E.—Associate professor of mechanical engineering, University of Michigan, Ann Arbor.

[2] See S.A.E. JOURNAL, November, 1930, p. 609.

[3] See Bulletin No. 13, College of Engineering, University of Michigan, Sept. 27, 1924, pp. 79-118.

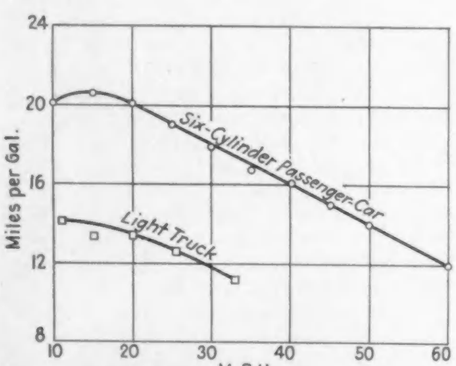


FIG. 1—CURVES SHOWING FUEL MILEAGE VERSUS VEHICLE SPEED

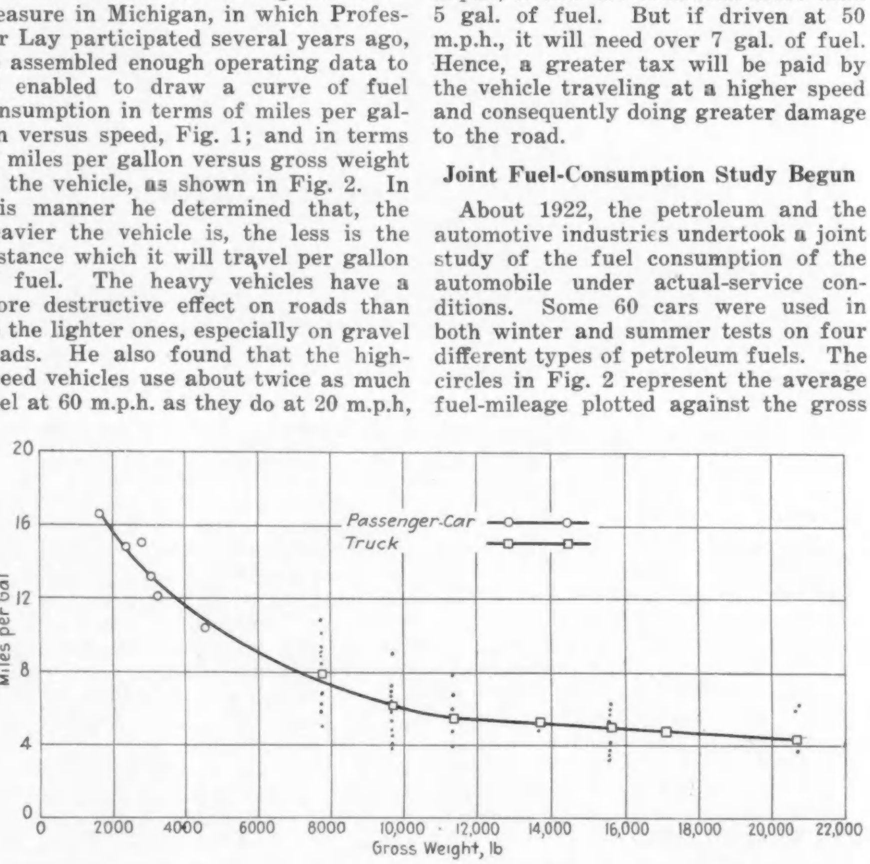


FIG. 2—CURVE SHOWING FUEL MILEAGE VERSUS GROSS VEHICLE-WEIGHT

weight of these cars. The squares represent the fuel mileage of some 90 motor-trucks, again plotted against the gross weight of these trucks. Fig. 2 therefore shows a decrease in the mileage as the gross weight of the vehicle increases.

Stated in another way, a light car with a gross weight somewhat greater than 1 ton may travel over the 100-mile road at 16 miles per gal. and use a total of 6⅔ gal. of fuel. A high-speed truck with a gross weight of 4 tons might be traveling at nearly the same speed, but it would need practically twice as much fuel. It must be noted that there is only a slight increase in fuel consumed with increased load among the heavier trucks, which are generally governed to a comparatively low speed.

It is thus made evident that a fuel tax will be levied on a vehicle in proportion to the distance it travels on the highway system, according to Professor Lay. The tourist who does not at present pay at all for the use of the roads, he states, will pay somewhere near his share. If a car is driven at high speeds that will by impact and abrasion cause increased damage to the roads, this will be penalized to a certain extent. If a light truck—especially of the high-speed type—is driven, it will be penalized in a measure for the extra damage done, while the heavier truck traveling at a lower speed is given credit for the lower speed. Moreover, judging from the lack of comment on the recent (1924) increases in the price of gasoline, it would be rather a painless method of extracting from the motor-vehicle operator the revenue necessary for the maintenance of those highways which are essentially motor-vehicle highways.

The other participants in the debate mentioned[4] were Hon. William M. Connelly, who presented arguments for the proposed Michigan gasoline and weight tax on motor-vehicles; and Sidney D. Waldon, who stressed the need for a 10-year highway program and analyzed motor-vehicle taxation.

[4] See Bulletin No. 13, College of Engineering, University of Michigan, Sept. 27, 1924, pp. 79-118.

Motor-Vehicle Taxation

Statement of Vital Underlying Considerations of Taxation To Pay for Highways

According to the Motor-Vehicle Conference-Committee, the Federal Government, State Governments and municipal governing bodies, constitute the actual or potential taxing jurisdiction. General taxes and special taxes are the types of taxes levied. The former are those which are levied indiscriminately upon all classes of property for the purpose of raising money to conduct the general functions of government. Ability to pay, rather than benefits derived, constitute the justification and the measure of the amount of general taxes paid by any one taxpayer. The ad-valorem taxes imposed by many States on the motor-vehicle as personal property illustrate what is meant by general taxation of the motor-vehicle.

Special taxes, on the other hand, single out certain classes of individuals to pay additional or peculiar taxes which are levied exclusively on such classes on the theory that the expenditure of these special taxes results in extra or exclusive benefit to those called upon to pay them. Annual registration and license fees, motor-fuel taxes, and similar impositions are examples of special taxation of the motor-vehicle.

The work being done by Federal, State and Municipal Governments in the way of constructing and maintaining improved highways upon which motor-vehicles can operate efficiently and economically is presumed to constitute benefit sufficient to support special taxation of the motor-vehicle. It is estimated that, for the year 1930 and for some years to come, the total of these expenditures for the three jurisdictions already mentioned will be one billion dollars or more annually.

Taxation To Pay For Highways

Four theories are stated by the Committee, as follows:

(1) *No Special Taxation Whatever for Motor-Vehicles.*— This theory holds that highway transport, being of the same nature and importance as public education, police and fire protection, should be taken care of entirely by general taxation levied upon Society-as-a-Whole in accordance with the ability of its individual members to pay, and not with reference to the amount and intensity of the use and benefits which any one of such individuals owning motor-vehicles may obtain from operating them on improved highways. In other words, it regards special levies on the motor-vehicle as uneconomic and unfair.

(2) *Special Taxation of the Motor-Vehicle to Pay Everything.*— The second theory goes to the other extreme and insists that Society-as-a-Whole should not in any way be subjected to taxation for the construction and maintenance of improved highways, on the ground that the performance of this governmental function results exclusively in benefiting the motor-vehicle owner and user. The theory holds that the motor-vehicle owner and user should pay special taxes to cover the entire burden, which aggregated over a billion dollars for the year 1928.

(3) *General Taxation for Construction; Special Taxation of the Motor-Vehicle for Maintenance.*—The third theory holds that Society-as-a-Whole, including owners and non-owners of motor-vehicles, should pay general taxes to provide the capital investments necessary to construct improved highways, but that motor-vehicle owners and users, as a separate and distinct class, should be called upon to pay special taxes to maintain improved highways.

(4) *Adjustment of General and Special Motor-Vehicle Taxation on the Basis of Use of Motor-Vehicle Funds for Such Highway Improvement As Does Not Constitute an Unfair Burden on the Individual Motorist.*— The fourth theory, and the one which is steadily gaining ground in the United States, holds that the amount of special taxes levied against the individual motor-vehicle user shall not constitute an unfair burden. This amount determined, such funds shall always be limited to improvement of highways for general motor-vehicle use and shall be devoted first to maintenance costs. In States where a surplus remains after such motor-vehicle-highway maintenance needs have been cared for, this surplus should be used to pay a substantial share of all other costs of highways of general motor-vehicle use or may be used to defray all or part of the costs of bond issues to expedite construction of economically desirable motor-vehicle highways.

The Motor-Vehicle Conference-Committee is strongly impressed with the fairness and economic wisdom of the fourth theory and, using it as a basis, has set up a code of Sound and Equitable Principles To Control Special Taxation for Motor-Vehicles, which, in its judgment, should underlie all laws dealing with the subject.

Ordnance Advisory Committee Confers

THE Ordnance Advisory Committee of the Society held its 23rd semi-annual meeting in Cleveland, on Nov. 17, 18 and 19. A full and varied program made this meeting one of the best that this important Committee has ever held.

The following members were present:

A. F. Masury, Mack-International Motor Co., Chairman
H. W. Alden, Timken-Detroit Axle Co.
George A. Green, General Motors Truck Corp.
A. J. Scaife, White Motor Co.
H. T. McDonald, Caterpillar Tractor Co.
A. W. Herrington, consulting engineer
G. A. Round, Vacuum Oil Co.

The following, also members of the Committee, were unable to attend:

P. E. Holt, Caterpillar Tractor Co.
W. G. Wall, consulting engineer
F. C. Hecox, Cadillac Motor Car Co.
E. F. Norelius, Monarch Tractors Corp.
J. F. Winchester, Standard Oil Co. of New Jersey

Ordnance Department representatives present were:

Lieut.-Col. C. M. Wesson, U.S.A.
Major L. H. Campbell, Jr., U.S.A.
Major W. A. Borden, U.S.A.
Major E. A. Lynn, U.S.A.
Capt. John K. Christmas, U.S.A.
H. A. Knox, Ordnance Department, U.S.A.
W. F. Beasley, Ordnance Department, U.S.A.

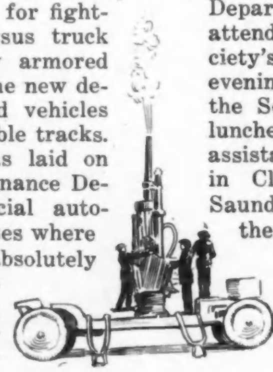
Participating in the meeting were also the following:

King C. White, Cleveland Tractor Co.
A. K. Brumbaugh, commercial engineer, White Motor Co.
R. E. Laisy, engineer, White Motor Co.
John A. C. Warner, general manager, Society of Automotive Engineers
C. B. Veal, assistant general manager, Society of Automotive Engineers

New Development Problems Considered

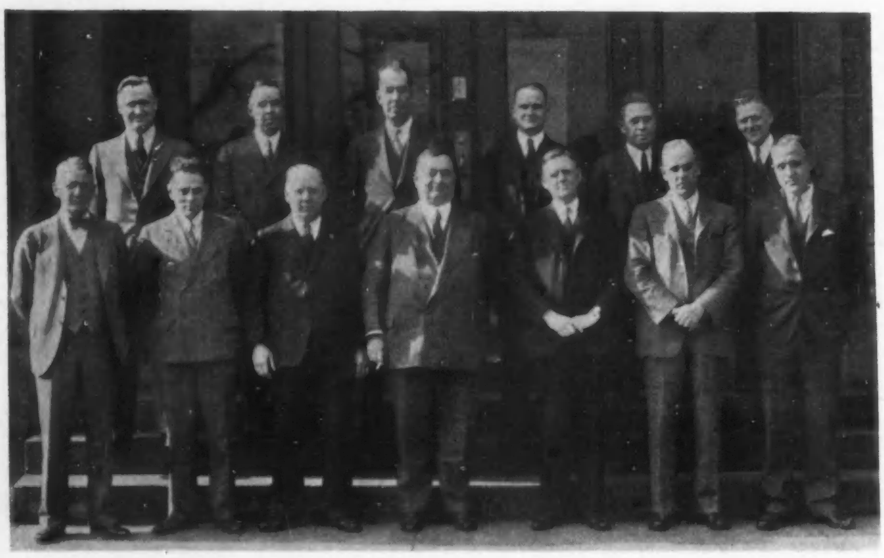
The first day's session was devoted to two formal meetings at which were discussed the technical problems involved in the new developments which the Ordnance Department has under way. Some of the problems discussed were maximum practical speeds for track-laying vehicles; use of aviation-type engines in tanks; present status of air-cooling; practicability of various wheel-and-track vehicles; six-wheel four-wheel-drive vehicles for cross-country transport; heavy-duty transmissions, with particular reference to means of gearshifting; lubrication of heavy-duty engines; worm drive for fighting tanks; passenger versus truck chassis for use in heavy armored cars; and possibilities of the new developments in half-tracked vehicles using rubber or other flexible tracks.

Particular emphasis was laid on the desirability of the Ordnance Department developing special automotive vehicles only in cases where military requirements absolutely dictate, leaving to the automotive industry, wherever possible, the development and manufacture of the great quantities of more or less standard vehicles. By intelligently compromising the military requirements with the vehicles that are commercially available, the Army is given the full benefit of the rapid developments in the automotive industry and there will be available at once upon the outbreak of war a large supply of reliable equipment. As a corollary to this, the War Department should concentrate on the military equipment of a vehicle and leave the development of the integrated chassis to the industry.



Guests of Cleveland Section and Ohio Industrial Plants

Besides the formal sessions in Cleveland, the members of the Committee were guests of the White Motor Co., under whose auspices the meeting was held. The Committee and the Ordnance Department representatives also attended the meeting of the Society's Cleveland Section on the evening of the 17th as guests of the Section, and were tendered a luncheon by King C. White, the assistant ordnance district chief in Cleveland, and a dinner by Saunders Jones, vice-president of the White Motor Co. The White factory and the plant of the Aluminum Co. of America in Cleveland were inspected. In Akron the party were the guests of the Goodyear-Zeppelin Corp. and the Firestone Tire & Rubber Co. The activities included an inspection of the new giant Navy dirigible being built in Akron by the Goodyear-Zeppelin Corp., rides in the Goodyear airships and inspections of the tire factories.



ORDNANCE DEPARTMENT REPRESENTATIVES AND MEMBERS OF S.A.E. ORDNANCE ADVISORY COMMITTEE GATHERED FOR SEMI-ANNUAL MEETING IN CLEVELAND

(Front Row, Left to Right) Col. H. W. Alden, C. B. Veal, A. J. Scaife, Col. A. F. Masury, Lieut.-Col. C. M. Wesson, Major L. H. Campbell, Capt. J. K. Christmas (Back Row) Major E. A. Lynn, Lieut.-Col. H. A. Knox, Major A. W. Herrington, H. T. McDonald, W. F. Beasley, Major W. A. Borden

Importance of Committee's Work

Col. C. M. Wesson expressed considerable gratification at the Society's cooperation with the Ordnance Department of the Army, his observations being substantially as given in the following paragraphs.

The Society's Ordnance Advisory Committee was organized in 1919, the first meeting being held in the City of Washington, Sept. 15 and 16, of that year. The Committee consists of prominent automotive engineers and leaders in the motor industry appointed by the Society to advise and assist the Ordnance Department in its automotive work.

Meetings are held approximately semi-annually at such places, selected by the Chairman, as offer opportunities to view activities having a bearing on the work of the Committee. The meetings are attended by officers and engineers of the Ordnance Department engaged in the development of

LIEUT.-COL. C. M. WESSON, U. S. A.

fighting tanks, tractors, armored cars and other special automotive equipment for military use. The late Coker F. Clarkson took a keen interest in this work and was usually present at the meetings.

The increasing importance of motorization and mechanization, on which great sums are being spent by foreign armies, has made the work of this Committee of more importance each year. This is particularly true because the demands in military service as to power, speed, endurance and cross-country mobility are usually considerably ahead of the commercial requirements, and the advice of the leaders in the industry is needed to show the trend of development. If in no other way the value of this Committee to our Government is shown by the fact that, with the very limited funds available, we have consistently built tanks and other military automotive vehicles which are the equal and in many cases the superior of similar vehicles built abroad.

In addition to the formal activities of the Committee, there is considerable informal cooperation between the members and the Ordnance Department. The attitude of the Ordnance Department can best be expressed in the words of the Chief of Ordnance, Major-General Samuel Hof, who said recently:

"The Ordnance Department appreciates the advice and cooperation of the S.A.E. Ordnance Advisory Committee, and I wish to thank the Society for its whole-hearted and unselfish participation in this patriotic work, the full value of which may not be apparent until we confront another National emergency."

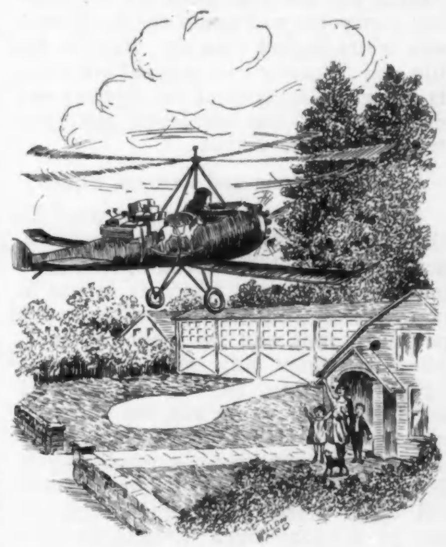
The New Yorker Rides the Windmill

IN THE INTERESTS of aviation we allowed ourself to be wafted gently up over New Jersey last week, in an Autogiro. We felt like a dandelion seed. We even took hold of the Autogiro's controls, and felt even more like a dandelion seed. This rare device of the upper regions is not airplane, not balloon, not dirigible, not helicopter—it is a Spanish windmill plane, that holds you up largely by a four-bladed horizontal fan, slowly rotating. It is like an airplane that has been soothed and calmed down; it is like an airplane to which someone has said: "There, there."

Possibly you have seen an Autogiro in the newsreels, or in the air over Manhattan. It has a fuselage, a motor, a propeller, just as any ordinary plane has, but it has no wings to speak of—just rudimentary fins which serve to balance it. The windmill overhead does the lifting. This windmill runs without benefit of motor; it twirls for the same reason that a pinwheel twirls when you push it through the air. Flying along in an Autogiro, you can cut your motor, and the windmill goes right on twirling overhead, the plane loses headway, slows down, and begins to settle toward earth. If there is a wind blowing, the machine will even drift backward. Our pilot landed it backward, to show us. It feels very funny, landing backward, with a slight plop.

The Autogiro is well known in aviation circles, but except for a few people like Thomas Edison and ourself, the lay public knows nothing about it. Edison went out to the Newark airport the other day, took one look at the plane, and said: "That's it." We went one step further than Edison; we got in the thing and went aloft. The controls are like those of an ordinary plane. There is, in addition, a clutch, which is used to start the rotor rotating. Once spinning, it carries on by itself, independently of the motor. You can be a pretty slipshod pilot and get away with it. Suppose you take off to fly over a barn and find you aren't going to make it. No problem at all—you pull the stick back and the contraption shies away from the barn the way a jumping horse shies away from a high fence after running at it full tilt.

We hear that the Autogiro is to be manufactured commercially here soon and will sell for about what a plane of like power sells for. And, although it looks like something Jules Verne thought of, it will actually land in one's flower garden—or, if one is fussy, in one's neighbor's flower garden. We



were much impressed by our flight, and we want an Autogiro more than we have wanted anything since we wanted a pair of rabbits.—*The New Yorker.*

News of Section Meetings

(*Continued from p. 635*)

quate but obsolete. "The city's investment in obsolete traffic equipment is appalling," he said. He believes that the traffic-control system of Indianapolis could be brought up to date with money now being spent on experiments and other devices.

Inadequacy of the State highway control was brought out by A. H. Hinkle, head of the State highway maintenance department, who said that the total State police force is but 35 and the highway department has no voice in directing the State police.

The crying need of the time, as brought out by Mr. Todd and Chairman Schwitzer, is that cities and States employ traffic engineers who shall approach the problem from the engineering viewpoint and apply the most modern methods and devices. Besides the life and property loss, a great time loss is inherent in many of the devices and systems that are employed generally throughout the Nation.

Demonstrations and Lantern Slides

Mr. Todd's talk was illustrated by the demonstration of the E-M vehicle-actuated control developed by the company he represents, which is in use in many cities. This device consists of a pavement unit and the machine itself, which operates any type of signal lights. Set up for double arterial movement, the model and the tiny toy cars were shown in every variant of traffic movement, under a machine-gun fire of questions by the engineers, city and State officers and others present who have spent much thought on city traffic movement. Not a single question or problem seemed to stump the machine or Mr. Todd, who gave prompt answers to all questions and demonstrated his point.

Later, a series of lantern slides was thrown on the screen to show scores of important street intersections in many American cities where such devices have handled traffic with safety, reducing accidents and freeing the policemen to perform their proper duty of policing the streets to suppress inefficient and dangerous driving. Capt. Harry M. Franklin, of the Indiana State Police, claims that the accident factors on any highway or street are the reckless drivers, who constitute not more than 20 per cent of all drivers.

Among the slides shown were those of the traffic layout and a maze of eight main street-intersections in Providence, R. I., where, under the old methods employed, eight traffic men were needed to handle the traffic. The vehicle-actuated device freed the men from the corners, cut down the number of accidents and the property loss very markedly, and is speeding up the traffic and handling it more efficiently day by day, asserted Mr. Todd.

Among others who spoke of the inadequacy of city methods and the need of such modern devices was Todd A. Stoops, secretary-manager of the Hoosier Motor Club, who asked the engineers to get behind movements to persuade city officials to try out scientific new methods and advance faster toward safety measures and more expert traffic management.

Improvement from Depression

Art, Research and Specialization Bringing Better Cars, Woolson Tells Canadian Section

RADICAL changes in the design and construction of automobiles in the next ten years, which would make the present motor-car look more antique than the car of ten years ago now appears, were presaged by Harry T. Woolson, chief engineer of the Chrysler Corp., in an address before the Canadian Section at the monthly meeting at the Royal York Hotel, Toronto, on Nov. 19.

Owing to the Cleveland Section meeting, there was a somewhat smaller attendance of 60 members and friends. Chairman A. S. McArthur presided and Bob Combs, last year's Chairman, was elected as the Section's representative on the Nominating Committee of the Society and also as representative on the Sections Committee. F. N. Horton was nominated as alternate for Mr. Combs on both these committees. Alex Bentley, Chairman of the Membership Committee, reported 101 active members, 25 applications on file and 26 prospects. The next meeting was fixed for Dec. 17, and formation of a Reception Committee was announced by the Chairman, who refused, however, amid laughter, to define its duties.

Mr. Woolson's address was on Automotive Engineering Methods and Organization and was followed by a motion picture of activities at the Chrysler factory. Automotive engineering, he said, which a few years ago was supposed to deal only with such grimy, oily parts as cylinders, pistons and axles, has now expanded to take in the finer arts. Chrysler now has an art department that is considered of major importance.

A car, like a beautiful painting, can be ruined in appearance by a few slight changes in its lines. The chassis may be the acme of perfection and developed to the *n*th degree, but if it is not clothed in an attractive dress, remarked Mr. Woolson, it will not be a commercial success. Months of work was put in on Chrysler radiator appearance.

An engineering department must not only keep abreast of the times, but look ahead. Resting on the oars is sure to end in failure. To survive, it is necessary to continually fight upstream. The research department is endeavoring to look ahead, trying to visualize what advances in automobile construction may consist of over a period of years and to anticipate the next move.

Responsibility Follows Cars Through Factory Gate

Mr. Woolson said the organization he represents is in agreement with Chic Sales, believing in specialization and carrying out this practice to a greater extent than many other like organizations. It has assigned an engineer to radiation and cooling, and this had worked out very satisfactorily. Several specialists are employed to watch the rubber end of the industry, and they can well be afforded, as the value of rubber used by the corporation in 1929 was over $10,000,000.

The speaker emphasized the tremendous importance of continually checking the various products because a little slip in design may mean vast losses. Engineering responsibility does not end when drawings and specifications have been turned over to the manufacturing department; the finished product must be followed out through the gate. With that object in view, ten new production cars are secured every night for engineers in the central organization to drive home and check up and report on the following day.

Among other things, Mr. Woolson mentioned that the aluminum piston has called for a great deal of engineering work, one, and at times two, experts having devoted their time exclusively to the designing and testing of such pistons.

In concluding his address, Mr. Woolson said that the business depression of the last year has given an added impetus to all engineering work. With

production and sales down, engineering has been called on to put forward an unusual effort toward perfecting products. Subsequent constructions will demonstrate that the depression has not been an unmixed evil when consideration is given to the numerous improvements that have resulted.

Northwest Has Big Meeting

Dinner, Free-Wheeling, Society's Activities and Motion Pictures Interest Nearly 100 Attendants

VERY interesting was the November meeting of the Northwest Section, held at the Engineers Club in Seattle on Nov. 14. A. J. Underwood, from the Society's headquarters, explained the activities and policies of the organization; H. E. Johnston, engineer with the Studebaker Corp., gave a talk on free-wheeling as applied by his company; and, to round out the program, P. E. Sands, dean of dealers in the Northwest and pioneer good-roads booster, showed motion pictures of the recent automobile caravan from Seattle to Hazelton, British Columbia, 1100 miles north on the proposed Pacific Highway extension to Alaska. Mr. Sands also showed slides of "stills" taken on a similar trip that he made in 1911 in a Studebaker Flanders car which was the first automobile into Hazelton.

Don F. Gilmore, Section Chairman, who presided, announced the resignation of the vice-chairmanship by Walter Jones, who has moved to Corvallis, Ore., and is now within the territory of the Oregon Section. A. M. Jones was elected by acclamation to fill his unexpired term. Robert Taylor, former Section Chairman, was elected delegate, and Sherman Bushnell alternate, on the Nominating and Sections Committees of the Society.

The meeting was fully attended, every place being occupied at the dinner that preceded the technical session, about 100 being present.

Society's Activities Explained

Mr. Underwood, in his address, complimented the Northwest Section for its progress and urged that the members support the officers, upon whom much work devolves, to make a success of the meetings and the Section. The scheme of organization of the National body, with its specialized departments and 21 regional Sections, was explained. Members were urged to make use of the TRANSACTIONS, which are available to them for the asking.

Work done by the Society in research fields and the improvements accruing from the cooperative fuel research and from standardization, which has resulted in about a 30-per cent saving in costs of manufacturing cars, were mentioned. Application of standardization in aeronautics is now being made, said Mr. Underwood, advantage being taken of experience in the automobile industry. The information bureau, the employment department, research work now under way in Diesel fuel-oil and other activities were also explained. More inquiries for the services of competent men are now coming in from the Middle West and East, he said, as conditions are improving in those regions.

Free-Wheeling Described

The free-wheeling device, as applied by the Studebaker Corp., is simple and sturdy, said Mr. Johnston in his address. An over-running clutch of the roller-cam type is incorporated in the transmission. Application of the roller clutch to cars is not new, having been in vogue in Europe for some years, but Studebaker is first to use the device in this Country. Installation is possible in the transmission, back of the transmission, in the clutch or in the rear axle.

As the free-wheeling car has met traffic conditions in the mountains and in cities it has been approved by law-enforcement officers. A saving of 20 per cent in oil and 12 per cent in gasoline and other advantages were claimed for it. The speaker told of the effect on tires, brakes and generator and said that results show little difference over the conventional transmission. A safety factor is that the driver can always get into gear, even with the car running rapidly in neutral or in free-wheeling positions. Tests showed that no change was required in the cooling system, although there is slightly more heating when free-wheeling because of reduced fan action. The brake capacity has been increased 20 per cent on the new models. A small increase in wear on brakes is largely offset by the fact that in quick stopping the engine can overrun the wheels, and in slow stops the compression assists in reducing speed.

A high degree of interest in the subject was shown by the numerous questions asked of Mr. Johnston by the various members.

The meeting closed with the showing of the Seattle-Hazelton pictures.

Modern Parking Garages

How Big-City Problem Is Being Met Described and Shown to "Met" Section

ON THE EVENING of Nov. 19 some 200 members and guests of the Metropolitan Section heard Milton A. Kent, president of the Kent Garage Companies, and Sidney R. Dresser, executive engineer of the same organization, talk on What Engineering Has Done for the Garage.

In a brief business session Joseph A. Anglada was elected Metropolitan Section representative on the Nominating Committee of the Society, with William E. John as alternate, and Neil MacCoull was chosen for the Sections Committee, with Jerome C. Hunsaker as alternate.

The gathering took place at the A.W.A. Clubhouse, New York City, where dinner was served before the meeting was called to order at 8:00 p. m. Chairman Austin M. Wolf presided. Before introducing the principal speakers of the evening, he presented Capt. Con. W. Willemse, who told about interesting experiences he had during his many years of service as a police officer in New York City.

Development of the garage and its relation to the automotive industry were discussed first by Mr. Kent, who said that New York City is slow to meet the traffic problems which the automobile has brought. Three things are needed; namely, express highways, no street parking and modern garage facilities; but, said Mr. Kent, it seems likely that the city will get these items in reverse order.

Mr. Kent mentioned the terminal problems of the railroads and pointed out that an analogous condition exists for automotive transportation. The construction of combination buildings with office space and garage facilities under the same roof is being recognized more and more, he said, as an intelligent method of providing the needed automobile terminals and, at the same time, making the office rentals more attractive. In this the Pacific Coast is leading the way.

Following this talk a motion picture was shown to emphasize the effect on traffic congestion of curb-side parking in a number of cities and to show in detail the Kent Garage methods, which were explained from the engineer's viewpoint by S. R. Dresser.

Electric Parker and Control Device

Although known to the public as the automatic garage, the system developed really provides electrically op-

erated, manually controlled parking, said Mr. Dresser. He read an amusing description that appeared some months ago in a magazine telling how the electric parker slips off the high speed, self-levelling elevator to grab the surprised car and haul it on board.

A number of pictures were shown of installations in New York, Chicago and Philadelphia, with particular attention to the details of the electric parker and the control devices. Certain improvements were mentioned, including the recently designed brakes that prevent coasting of the parking dolly and speed up car handling. A chart of car-space costs with both Kent and ramp-type buildings was explained.

Mr. Dresser answered many questions about such points as the handling of front-drive cars and switching requirements. He also told something about the unusual car-handling system of the Chicago Pure Oil Co. garage when that building was mentioned by William J. Mayer, a former member of the Pennsylvania Section.

The meeting then adjourned to the new Kent Building a few blocks away, where an inspection of this modern automobile terminal was made and further questions were answered.

For the afternoon of Dec. 6 the Metropolitan Section announces a visit to the Chrysler Building at the invitation of Byron C. Foy, vice-president of the Chrysler Corp. The regular monthly dinner and meeting will be held at 6:30 p. m. on the evening of Dec. 10 at the A.W.A. Clubhouse, 357 West 57th Street. Paul Goldsborough, president of Aeronautical Radio, Inc., will speak on Aircraft Radio. There will also be an exhibition of an aircraft engine and aeronautic radio devices, furnished by the Western Electric Co. and the Radio Marine Corp.

Syracuse Section Told about Aircraft Carriers

NAVAL airplane-carrier history and development were reviewed and three motion-picture reels illustrating the methods of handling airplanes on the carriers were shown by Lieut. L. D. Webb at the meeting of the Syracuse Section on Nov. 6 in the Hotel Syracuse. Lieutenant Webb was formerly attached to the U. S. S. Lexington but now is in charge of propeller work at the Bureau of Aeronautics of the Navy Department.

Forty-two members and guests of the Section attended the meeting, which followed an informal supper served by the hotel, at which those present had an opportunity to become better acquainted with their fellow members. Before the meeting the guests dined with Section Chairman E. S. Marks, Vice-Chairman Charles P. Grimes, Secretary L. W. Moulton, Treasurer M. R. Potter, and R. B. Beauchamp and R. N. Wright, members of the Section Governing Board.

The technical session was presided over by Mr. Marks, at whose request each member and guest introduced himself at the opening. John A. C. Warner, General Manager of the Society, was introduced by the Chairman and spoke of the growth of the Society and its standardization and research work, which has given it world wide recognition as the leading engineering organization in the motor-vehicle and aeronautic fields.

England Started Carrier Development

Lieutenant Webb, in his address, said that aircraft operation with the fleets divided itself in the beginning into two considerations: the launching of small seaplanes from catapults attached to battleship turrets and the operation of large numbers of aircraft of various types from specially constructed carriers. Naval aeronautics differs from ordinary aviation in the necessity of landing and taking off in an average distance of 100 ft.

Experiments in taking off were made from the U. S. S. Birmingham as early as 1910. In January of the next year the first successful landing was made on the quarterdeck of the Pennsylvania. At that time this was regarded as stunt work and its practical value was not perceived until the World War. In 1918 and 1919 several United States battleships operated single seaplanes from turrets but, although many methods were tried, they were not successful enough to warrant their use in actual warfare.

About that time, however, said Lieutenant Webb, the British navy conducted from an airplane carrier a successful raid on a German aeronautic center near the North Sea and, on the basis of this performance, the United States Congress authorized the conversion of the collier Jupiter as an airplane carrier. After complete refitting, this vessel became the Langley, known affectionately in the Service as "The Covered Wagon." The satisfactory results of experiments on the Langley brought about the reconstruction of the Lexington and Saratoga. These ships were planned as cruisers but were altered as the result of the Washington Arms Conference.

Driven by the largest marine power-plants in existence, the Lexington and Saratoga develop 210,000 shaft horsepower and have a top speed of nearly 35 knots. The former holds the world cruising record, having run from Los Angeles harbor to Honolulu in 72 hr. 36 min. Despite the tremendous power developed and complications caused by cramping the huge engines into a restricted space, both of these vessels are singularly free from trouble.

Lieutenant Webb's talk closed with general discussion and questions from the members.

Water-Jacket Corrosion Studied

Oregon Section Hears Valentine Gephart on the Causes and the Preventive Measures

BEFORE a gathering of nearly 100 members of the Oregon Section in the Spanish room of the Multnomah Hotel in Portland on Nov. 13, Valentine Gephart reviewed briefly the work he has done in determining the causes of corrosive action in water-jackets, the effect of different corrosive chemicals and the properties of these ingredients that cause undesirable effects.

Dinner was served while a tropical atmosphere was maintained by the Songsters of Hawaii, who played Hawaiian melodies.

A. J. Underwood, director of Section activities of the Society, spoke upon the functions of the Section, the various activities of the Society, and some of the work the Society has accomplished.

Impurities in Cooling Water

Development of engines with higher compression-ratios, efforts to economize in weight and size of cooling systems, and the increasing tendency of drivers to travel longer distances, necessitating refilling the radiator at many different places, increase the tendency to corrosive action and make the resultant lower cooling efficiency more serious, said Mr. Gephart. Analyses of available cooling-water samples obtained from various places up and down the Pacific Coast from northern Washington to southern California showed that the impurities contained in the water, expressed in terms of calcium carbonate, varied from 2 to 312 grains per gal.

This showed that treatment based on a chemical analysis of the water, as is usually done for boiler-feed water, is not practicable for motor-vehicle cooling water, as the treatment would have to be effective for waters of different impurities. Moreover, the treatment would have to be effective for at least six months, as the motor-car operator would not bother to make treatments more frequently.

A further study of the problem showed that nearly all radiators are made of either copper or brass and are, therefore, subject to very little corrosive action by any of the water com-

monly used for cooling. The engine block, on the other hand, being of some ferrite alloy, is quickly affected by the corrosive action of impurities.

Preventive Measures Indicated

Continuing the investigation, it was found, according to Mr. Gephart, that the greatest corrosion was caused, not by water containing considerable quantities of impurities, but rather by water containing the weaker solutions of acids or alkalis. Therefore, very accurate means for measuring the degree of acidity or alkalinity were set up in the laboratory. The basis of this measurement was a determination of the hydrogen-concentration ratio. The materials used for engine-block castings were found to be of such chemical analysis that they were affected only when the pH ratio was below 7.0.

Explaining briefly the hydrogen ion concentration theory, Mr. Gephart pointed out that, under the theory of electrolytic dissociation, all liquids of which water is a constituent contain free H and OH ions. When the number of H ions exactly equals the number of OH ions, the solution is said to be neutral. If the number of H ions exceeds that of OH ions, the solution is said to be acid; and, if the solution contains an excess of OH ions, it is said to be alkaline.

The problem of treating internal-combustion-engine systems for corrosion then resolved itself into, first, the addition of chemicals to bring the water to zero hardness; second, the production of a colloidal film that would clothe each particle of sediment, preventing it from cohering with other particles; and, third, the deposition of the same colloidal film, with a constant pH ratio of between 7.0 and 7.4, on the metallic surface of the block exposed to the cooling solution.

High-Tooth-Pressure Lubrication

Important Discussion on Lead-Base Lubricants by Authorities at Cleveland Meeting

WITH an enthusiasm that only a little known and decidedly controversial subject can produce, 325 members of the Cleveland Section, guests from the Detroit, Pittsburgh, Buffalo and other neighboring Sections, along with many interested friends, gathered in the evening of Nov. 17 at Hotel Statler for the second Cleveland Section meeting of the season.

J. A. Edwards, of the Jesco Lubricants Co., presented the first paper on the program and discussed the manufacture and use of lead-base lubricants as applied to automotive differentials and transmissions. E. Wooler, chief engineer of the Timken Roller Bearing Co., described the methods designed for testing such lubricants, and told of the action of such heavy-duty lubricants on bearings and gears in general. Prepared discussion by representatives of many prominent oil manufacturers furnished a very interesting climax to the meeting.

After a short concluding discussion of the subject by Dr. H. C. Dickinson, of the Bureau of Standards, the meeting adjourned to examine in detail the "scuffing machine" and the "contour-magnifying machine" which were set up in the assembly room by Mr. Wooler, complete and ready for operation. Examples of the tests described in the paper by Mr. Wooler were shown and demonstrations were made of the operation of the machines, with an interpretation of the results by the speaker and his assistants.

Guests arriving early were entertained at miniature golf, with the links set up in a foyer of the hotel lobby.

The meeting was opened by a short inspirational talk by C. S. Maltby, of the Ohio Bell Telephone Co., on the subject, Metropolitan Cleveland—Its Future. He predicted that the metropolitan area would have a population of approximately 2,000,000 persons by 1950, in the same area that now contains slightly more than 1,000,000.

At a brief business meeting prior to the papers, O. A. Parker was elected to represent the Section on the Nominating Committee of the Society, with A. K. Brumbaugh as alternate, and D. S. Cole was elected a member of the Sections Committee of the S.A.E.

A. J. Scaife, acting as meeting sponsor, then introduced John A. C. Warner, Secretary and General Manager of the Society, who gave an interesting outline of his impressions of the subject of Lead-Soap Lubricants.

Results of Tests Made

The advent of improved alloy steels, Mr. Wooler said, for use in gear teeth has permitted the manufacturer of differential and transmission gears to use smaller units in the car of today than was thought of several years ago. In one case cited, a car that in 1924 had a tooth load of 925 lb., has today a tooth load of 1425 lb. This condition, coupled with excessive deflection of some carrier assemblies, gears and pinions, has given localized loads that break down a petroleum oil film and produce scuffing. Hypoid gears, by virtue of their angular action, will not operate satisfactorily under heavy loads if only a petroleum oil is used as a lubricant. The addition of 3 to 15 per cent of lead oleate to such an oil will improve its carrying capacity so that the gears will work satisfactorily even under heavy loads. However, such a compound will generally result in rapid wear of not only the antifriction bearings but also the tooth profile itself.

Conclusions Reached from Results

In recognition of the value of definite data on this subject, Mr. Wooler has directed a well-planned study of the behavior of various gear and bearing lubricants and designed two machines, one to test the abrasive properties of the compound and the other to test the scuffing properties. As a result of tests performed on these machines, it has been found that:

(1) Lead-soap-base grease is generally not stable. A tendency exists for lead oxide to separate out and so produce a slight lapping action on antifriction bearings and gear teeth.

(2) Ordinary heavy-duty lubricant filler-bases such as calcium and sodium do not appreciably increase the strength of the lubricant film.

(3) The addition of sulphur, either free or combined, will improve the load-carrying ability of a lubricant to a considerable extent. This may be combined with lead soap, but there is a definite lapping or wearing effect, due to the sulphur itself, which is comparable to the action of the lead oxide derived from lead soap. Combined sulphur, it was found, gives less of this action than the free material.

Advantages of Lead-Base Lubricants

J. A. Edwards, of the Jesco Lubricants Co., pointed out that, since the new automotive designs require lubricants to withstand these higher tooth-pressures, and as a properly compounded lead-soap lubricant will do this where a pure petroleum oil will break down, it seems logical to adopt this newer compound for such service. He stated that such a compound gives, in addition to higher tooth-pressures, low cold-test, ease of shifting in cold weather, a low coefficient of friction under high pressures and a rate of antifriction bearing wear which may be somewhat more than for straight petroleum oil yet need not necessarily be excessive. The evils derived from this slightly increased wear are far less than would be encountered were gear-tooth scuffing to occur. The secret of minimum bearing wear due to this type of lubricant lies, Mr. Edwards said, in the proper compounding of the grease at the time of manufacture. He also cited examples of lead-base lubricant specifications as put out by gear manufacturers which show wide divergence. He requested that a standard be adopted in such specifications, so that the grease manufacturers will be able to put out a standardized product.

A Compromise Seems Necessary

Discussion following the papers emphasized the point that at present all lubricants having good high-pressure lubricant-film characteristics produce more scuffing and bearing wear than a straight mineral oil. Therefore we should compromise between permitting excessive bearing-wear and protecting the gear teeth with such a lubricant, on one hand, and protecting the bearings and accepting gear-tooth scuffing with a straight petroleum oil, on the other hand.

A plea was made for the manufacturer to build gears that will give tooth pressures within the limits of good lubrication practice. Lubrication at very high pressures was classed as borderline lubrication, and high-tooth-pressure design was not recommended except where such design is imperative. It was also suggested that a coordinated study be made of the surface phenomenon of wear, through chemistry, metallurgy and microscopy.

Men prominent in the discussion were Robert E. Wilson, of Standard Oil Co. (Indiana); Dr. A. E. Becker, Standard Oil Development Co., of Elizabeth, N. J.; Mr. Bissell and Mr. Helm, of the Standard Oil Co. of Ohio; George A. Round, of the Vacuum Oil Co.; C. R. Noll, of the Gulf Refining Co.; Mr. Baudoin, of the Sinclair Refining Co.; Mr. Downey, of the National Refining Co.; W. E. Day, of the International Motor Co.; H. C. Mougey, of the General Motors Corp. Research Laboratory; Dr. H. C. Dickinson, of the Bureau of Standards, and Sydney Bevin, of the Tidewater Oil Co.

The Ordinance Advisory Committee of the Society attended this meeting in a body.

Schon Presents Truck Situation at Buffalo Meeting

UNDER the title, The Modern Trend of Transportation, Pierre Schon, of the General Motors Truck Co., told the Buffalo Section at its meeting Nov. 12 that motor-trucks will change as much in the future as they have in the last six or seven years and urged some concerted action by the manufacturers to secure the adoption by all States of the Hoover Motor-Vehicle Code or some similar uniform traffic regulations.

The meeting was held at the Hotel Statler, with 65 Section members and 46 guests present. A well-attended dinner preceded the technical session, among the guests being Mr. Schon and General Manager Warner, of the Society. Music was furnished by William Shaeffer, district manager of the Goodyear Tire & Rubber Co.

Mr. Schon's talk covered some of the information given in his two Annual Meeting papers entitled, Weight and Size Trends in Motor-Truck Development, published in the S.A.E. JOURNAL for August, and Motor-Vehicle Legislation and Taxation, published in September. As an indication of how the trend in trucks is changing, the speaker pointed out that one sees on the instrument board of trucks built four or five years ago only a switch key and an oil gage, whereas on present-day trucks there are a speedometer, a gasoline gage, an oil-pressure gage, a heat indicator, an ammeter and, in some localities, instruments too numerous to mention. In 9 out of 10 cases these are all inclosed in a handsome panel, indirectly lighted, and are seen on all well-known makes of truck.

Mr. Schon spoke at length on the great lack of uniformity in State laws and regulations in the matter of truck dimensions, weights and taxation, pointout out that in Ohio a truck and trailer are permitted to have a gross weight, with load, of 36,000 lb. on six wheels but if they enter New York State the weight is restricted to 28,000 lb. Some States do not permit the use of trailers at all. Again, the permissible over-all width of truck and body is limited variously to 90, 96 and 102 in. No two States have identical requirements, and this fact is detrimental to the manufacture and use of trucks.

The address was illustrated with nearly 100 lantern slides showing the great variation in wheelbase, frame width and length of frame from the back of the cab to the rear-axle center.

What Design Changes Do

Effect on Truck Body Building and Repair-Shop Equipment Told at Baltimore

EMPHASIZING particularly the need of cooperation and coordination between the manufacturers of motor-truck chassis and commercial-car body-builders in the standardization of chassis design, Edwin S. Ziegler, of the York-Hoover Body Corp., of York, Pa., presented a paper before 68 members and guests of the Baltimore Section at the monthly meeting on Nov. 19, which fully covered the salient practices in body-building operations.

A paper on Service Equipment, prepared by R. E. Manley, one of the pioneers in the equipment manufacturing business, was delivered by O. F. Kuhlman, of the Manley Mfg. Co., of York, Pa., and Bridgeport, Conn. In this paper the author recounted the gradual development of service equipment during the last 25 years and pointed out its significance in industry today, especially in the automotive industry where adequate garage equipment is a big factor in reducing maintenance costs and specially designed equipment is responsible for flat-rate accomplishments in shop operations.

Following Mr. Ziegler's talk, discussion brought out by Edward W. Jahn centered on the adaptability of aluminum as a material for body construction, in direct rebuttal of Mr. Ziegler's statement that steel had now become the accepted material for body building.

Villor P. Williams, president of the Automotive Corp. of America, manufacturer of the Davis car, and designer of the Parkmobile produced by The Parkmobile Corp., of Baltimore, gave a brief résumé of the operation of this device invented for the purpose of moving automobiles laterally. Mr. Williams explained his invention and outlined its purpose in response to Mr. Kuhlman's assertion that several new types of jack are being marketed to be installed permanently beneath the rear of cars for use only in raising the rear for tire-changing purposes. Mr. Williams declared that the Parkmobile should not be confused with a jack.

Progression from Wood to Metal

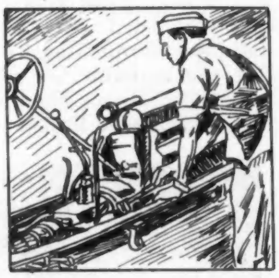
In his address Mr. Ziegler said in part that oak and ash framing, with poplar paneling, are the principal woods used in the building of wagon bodies and were used in the automobile body for a number of years. As designs in passenger-car bodies became more intricate and the car manufacturers improved the lines and appearance, some other material was sought that would lend itself to the swells and curves of the more advanced models.

Engineers of the larger manufacturers turned to aluminum as a logical substitute, because of its light weight and soft texture and, for a time, passenger-car and even commercial-vehicle bodies of the better grade were entirely covered with a sheeting of aluminum. Substitutes for wood paneling were invented and, in the construction of commercial bodies, fiber compositions were largely used. However, with the advent of nitrocellulose or lacquer paints the fiber panels are no longer used in large production.

Plywood still has its place in commercial-body construction, said Mr. Ziegler, principally for footboards and interior linings. The beautiful grain of a plywood liner, due to the fact that the plies are rotary-cut and display the natural grain of the wood, lends itself to an attractive natural-wood finish for the interior of the body.

While aluminum, fiber board and plywood are still used in volume-produc-

tion bodies, the genius of engineering that has given us enormous presses to form in any required shape, steel has now become the accepted material for body construction. In some instances the engineers have designed entire bodies of steel including framing, floor, roofs and doors, but this is not practical in commercial-body construction, because of crystallization and the fact



that production of any one model is too small to warrant the expense of dies; hence common practice today is to use the combination of wood framing and steel paneling.

Design Changes Prevent Economy

Commercial-vehicle bodies formerly were simply square boxes built for utility without regard to looks, but now much thought is given to appearance, often with sacrifices in utility, according to Mr. Ziegler. In the last five years, the height essential to practical delivery requirements has been sacrificed to secure a long rakish appearance, and the sedan-type panel body is now in strong demand.

There is always the danger of chassis-design changes making any particular chassis obsolete before enough bodies can be produced from a set of dies to make the body a practical merchandising product. In other words, lack of cooperation and coordination between chassis manufacturers and body builders makes this venture of die cost financially dangerous. This has greatly retarded the progress of body design, asserted Mr. Ziegler, who believes that this condition should be remedied. The body builder, with his capital invested, is producing a product so vital to the final sale and utility of the truck chassis that he should receive consideration and the cooperation of the chassis builder.

Repair-Shop Equipment

Mr. Manley, in the paper presented by Mr. Kuhlman, dwelt at some length on the flat-rate system in service shops. Its introduction and gradual development were directly made possible by uptodate service equipment. It would be interesting, suggested the author, to look into the future and try to foresee just what is coming in this equipment field. In the past, the car manufacturers have cooperated with the equipment manufacturer by extending their facilities for testing equipment to determine whether it met with the needs of the trade. They then published manuals setting forth the various items of equipment that would best meet these needs. They have stressed the importance of the equipment to the dealer so that he might derive the benefits of this modern help in obtaining better profits from his work.

Automotive repair-shop equipment can be likened to a certain extent to machine-shop equipment; that is, a factory that keeps its equipment up to date can meet competition in the market. The one great obstacle in the development of efficient automotive repair equipment is the yearly change in design of automobiles, which has made obsolete many lines of equipment and necessitated redesigning items of equipment that are comparatively young. This is an expensive factor but must be considered by the equipment manufacturer. Nevertheless we can look forward to greater developments in equipment that will increase the miles obtainable per dollar invested in the automobile.

Doolittle Contrasts American and European Aviation

COMMERCIAL aviation in the United States is much superior to the vaunted European lines, according to Lieut. James Doolittle, former ace of the United States Army Flying Service, talking before the Aviation Division of the Detroit Section on Nov. 10. He blasted the popular conception held by most Americans that European commercial airlines and other much publicized similar foreign enterprises are far in advance of American aviation.

American air travel is better organized, better managed, more efficiently operated and more independent than European aviation. Its equipment is more efficient and its airplanes much safer than those plying the foreign air routes, according to the speaker.

Government control of foreign aviation has stifled individual enterprise and hampered individuals in their efforts toward greater things in aviation, asserted Lieutenant Doolittle. The principal reason today for the existence of European airlines is the heavy governmental subsidies and control, whereas American lines have been more independent and have operated through popular support rather than subsidy. This shows a greater air-mindedness and pioneering spirit in America, which has made possible a more steady and healthful development of aviation in the United States.

School Boys Demonstrate Model Planes

The meeting was attended by 360 members and guests, 322 of whom attended the dinner. The technical session was opened by Chairman Peter Altman, professor of aeronautics at the University of Detroit, who introduced William B. Stout as temporary Chairman. Mr. Stout was pinch-hitting for Harold H. Emmons, who was in Washington on business for the Aircraft Development Corp.

Prof. F. M. Granger, in charge of aeronautics at the Cass Technical High School, of Detroit, introduced a number of his students who have attained fame as National champions in model-airplane building. These youngsters, ranging in age from 15 to 17 years, entertained the 400 guests with their little ships for about half an hour, when it became the duty of Mr. Stout to introduce the speaker of the evening, Lieutenant Doolittle, which he did after putting the audience in a most genial frame of mind by narrating one or two anecdotes based on a national characteristic of the Scots.

Lieutenant Doolittle's address was most interesting. After leaving the Army Air Service he visited by airplane from 40 to 50 foreign countries as the representative of an American airplane manufacturer, demonstrating airplanes to foreign military powers. He showed a number of slides graphically proving his statements regarding the inferiority of foreign air travel and airports to those of the United States. He gave comparative figures as to size, type and number of foreign airports, showing this Country to be far in advance of anything yet accomplished abroad. He lamented the fact, however, that American military aviation is fast

losing its first place among the powers of the world, and suggested that unless it is soon stimulated we shall be lagging far behind foreign military powers in this arm of our National defense.

Taub Addresses Students

COMBUSTION - CHAMBER and crankcase design were discussed by Alex Taub, chief experimental engineer of the Chevrolet Motor Co., at the second meeting of the season of the University of Detroit Student Branch of the Society on the evening of Oct. 24. He elaborated upon the location of the valves with respect to the firing point, making numerous sketches on the blackboard to show the best combustion-chamber designs used.

Revolutionary Airplanes Predicted at Milwaukee

BILL STOUT hit the aviation nail on the (cylinder) head when he said that airplaines will have to be designed to suit the public rather than the designing engineers. He went further and told the Milwaukee Section members and guests that we shall have to build airplanes that women will want to buy before the industry can possibly get on a production basis that will prove profitable.

The talk was given at the November meeting of the Section, which was held at the Milwaukee Athletic Club, Wednesday evening, Nov. 5. Seventy-five persons attended the dinner and 25 others came in later to hear Mr. Stout. Nearly one-half of those in attendance were guests.

The dinner and entertainment were a credit to the chef and the entertainment committee. Seven dancing girls put on several numbers, a gypsy couple performed on banjo and accordion, and a certain athletic young person performed physical gyrations which gave new ideas for stunt flying to the pilots who happened to be present.

"There is too much following of tradition, perhaps due to the fact that most of our engineers are working under the supervision of a board," remarked Mr. Stout, who quoted a saying to the effect that, "the only thing that can successfully work under a board is a worm."

"When a popular plane does come," continued the speaker, "it will probably be one designed by an unknown mechanic in somebody's barn. It will have to be one you can learn to operate in an hour or two, so that buyers can go to the factory, take a little instruc-

tion and fly home in if the weather conditions are good."

Mr. Stout had to leave immediately following his speech, so that, of necessity, the usual questions and answers were omitted. Several speakers, however, volunteered to add more light to the subject. Helpful comments were made by Harry L. Horning, who had introduced the speaker; by Capt. D. Risley, Jr., of the Shaler Co., and by John H. Geisse, of the Comet Engine Corp.

The high spots of the discussion, however, were remarks by Paul E. Schimmelpfennig, a guest, who made a plea for financial support to develop a revolutionary engine that will operate on interplanetary power and is based on an understanding of the fourth dimension. Mr. Schimmelpfennig's remarks evoked a great deal of laughter, but when he had concluded, Mr. Horning pointed out that, although some of the ideas seemed visionary, some such individual probably will wipe out hidebound tradition and bring about the development of an airplane that will really prove popular.

Airplane Landing-Gears Considered at Wichita Meeting

AN ADDRESS on Airplane Landing-Gears that embodied answers to queries previously submitted was given by John R. Cautley, chief engineer of the Bendix Brake Co., at the Nov. 13 meeting of the Wichita Section, at which about 40 members and prospective members were present. Much discussion which followed the talk was of interest to all present.

Some of the questions to which Mr. Cautley gave answers that were concise, informative and satisfactory to the interrogators were:

Is toe-in or dish to be desired in airplane landing-wheels? What are the prospects of hydraulic brakes for aircraft? And, what are the most common mistakes in brake installations?

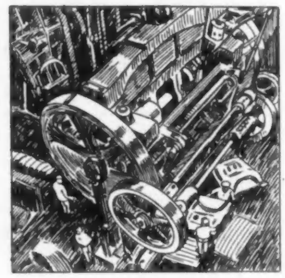
Mr. Cautley made it plain that Airwheels have their place on aircraft, but their place is in the rear of everything, or as tail-wheels. He stated that the purpose of a pneumatic tire is to absorb the shocks but that the physical characteristics of such equipment are such that the shock is not dissipated by the tire but is merely smoothed out. In this case "what goes down must come up" thereby causing much bouncing. To prevent this, he pointed out, is the duty of the shock-absorber, and if Airwheels were used without shock-absorbers the bouncing would be terrific.

Regarding the prospect for hydraulic brakes, Mr. Cautley said he thought that, in the case of wheels for transport airplanes, the air-operated hydraulic brakes have their place and that his company is working toward that end; but that, in the case of lighter jobs, the added advantage is not worth the extra cost.

One point the speaker made that impressed everyone was that ball-bearing brake-cable pulleys should be used to reduce friction, thereby increasing the braking efficiency of the hook-up. He pointed out that, owing to the static pressure on the pulleys, the average braking units have only about 30 per cent efficiency. By the use of ball-bearing pulleys this could be, and had been in some cases, increased to 60 per cent or more. He also said that if grease and dirt were kept out of the brake-bands there would be no such thing as locking brakes.

Toe-in and camber were said to be desirable in airplane construction as well as in automobile design. The wheels should be lined up in such a way that, with the weight of the airplane on the landing-gear, as in taxiing, the wheels will not be toed out or cambered out, which would make the airplane taxi very hard.

The talk was terminated by a short outline of the manufacture of wheels and some of the trouble experienced in producing wheels and brakes to meet



the rigid specifications the aircraft concerns are putting out. Mr. Cautley asked that the airplane builders standardize on the kind of a tail-wheel wanted and not ask the wheel manufacturers to make one to meet each builder's ideas. The Society is already at work on this project, said Mr. Cautley.

North Californians Hold Plant Inspection Meeting

MEMBERS and guests of the Northern California Section to the number of 275 were conducted on an inspection tour through the refinery of the Standard Oil Co. of California at Richmond, Calif., on Nov. 20, and 350 attended the dinner in the refinery cafeteria as guests of the company. A can of light household lubricating oil was presented to each guest. Entertainment was furnished by a sextette of Italian singers, who rendered a selection of college songs, in the singing of which the diners joined.

A great deal of hilarity was aroused by a mechanical robot operated by L. T. Wagner, of the oil company. This answered questions and made humorous remarks about various members of the Section present. Edward Meybem, superintendent of equipment for the City of Berkeley, was presented with a dry garbage can.

The visitors were transported about the plant in motorcoaches loaned for the occasion by various companies.

Excellent Papers and Discussion

Following the dinner and entertainment, the crowd ascended to the lecture rooms on an upper floor for the tech-

nical meeting, which was opened by Chairman E. H. Zetifuchs. A talk on Diesel fuel-oil research fostered by the Society was given by A. J. Underwood, director of Sections activities, and was well received.

Two excellent papers were presented by representatives of the oil company and illustrated with lantern slides, and there was much first-class discussion on them. George N. Neeley was a paper on The Mechanism of Journal-Bearing Lubrication, and J. R. MasGregor gave one on The Significance of the A.S.T.M. Distillation Test for Gasoline. Many requests were made by the members for copies of the papers.

At a brief business session J. Milton Davies, of the Caterpillar Tractor Co., was elected a delegate to represent the Section on the Nominating Committee that is to nominate officers of the Society for 1931, and J. F. Long, of the Curtiss-Wright Flying Service, was elected as a member of the Sections Committee of the Society for the coming year.

Rockne and Kettering at Annual Dinner

(*Concluded from p.* 629)

Two papers have been definitely scheduled for the General Development Session: The Use of Rolled-Zinc and Zinc-Base Die-Casting Alloys in the Automobile Industry, by Robert M. Curts, of the New Jersey Zinc Co.; and Riding Qualities, by Dr. Fred A. Moss, of George Washington University. A paper on Wheel Alignment is also tentatively scheduled for this session.

Diesel engines will, of course, hold the spotlight at the two Diesel-Engine Sessions, at each of which two papers will be presented. The Diesel-engine papers scheduled are the following: Practical Experience with Devices for Damping Torsional Vibration, by J. Barraja Frauenfelder, of the Sun Shipbuilding & Drydock Co.; The Operation and Maintenance of Diesel-Engine Motorcoaches, by A. A. Lyman, of the Public Service Coordinated Transport; Some Notes on the Development of Mobile-Type Diesel Engines, by C. G. A. Rosen, of the Caterpillar Tractor Co.; and Combustion Problems and Design of High-Speed Light-Weight Diesel Engines, by E. F. Ruehl, of I. P. Morris & De La Vergne, Inc.

Bodies, Production and Transportation

At the Body Session, a paper of intense interest to all concerned with that phase of automotive work will be given. At the Production Session, Machine-Tool Obsolescence will be considered. L. A. Blackburn, of the Oakland Motor Car Co., is writing the only paper to be presented; and collaborating with him are J. W. Brussel, of the Timken-Detroit Axle Co., and A. R. Fors, of the Continental Motor Corp.

The Transportation and Maintenance Session will deal with The Future Requirements of Motor-Truck Operation, and the Motor-Truck and Motorcoach Session will take up The Future Requirements of Motor-Truck Operators.

E. R. Armstrong has agreed to talk at the Aircraft Session, submitting a paper of general interest on The Possibilities of Heavier-than-Air Transoceanic Transportation with the Armstrong Seadrome. The program for the Aircraft-Engine Session will consist of two papers: Fuel Injection as a Substitute for Carburetion, by T. J. Campbell, of Wright Field; and Recent Developments in Air-Cooled Cylinders for High Mean Effective Pressures, by P. B. Taylor and Roland Chilton, of the Wright Aeronautical Corp.

Although the Annual Meeting program is a full one, it is expected that there will be ample time for discussion of the papers scheduled for presentation, as the Meetings Committee plans to follow the policy of having each author present his paper in abstract form within an allotted time. Strict adherence to the time limit imposed upon the author will result in leaving sufficient time at each session for the presentation of both prepared and extemporaneous discussion.

Otto Hermann

WORD has been received of the death, on July 30, of Otto Hermann, president and chief engineer of the Century Rotary Motor Corp., of Cortland, N. Y., as the result of a heart attack.

Mr. Hermann was born in August, 1876, at Pecs, Hungary, and studied in Europe as a portrait painter. He came to the United States in 1903 as a mechanical draftsman and became a naturalized citizen in 1914. In 1904 he invented an automobile loop-the-loop which was used in Barnum & Bailey's circus from 1905 to 1908.

Mr. Hermann settled in Providence, R. I., in 1909 and built an airplane driven by a rotary engine, in which he flew all over the United States at fairs and exhibitions until 1912. After that time he began the development of a new type of rotary engine which he completed at Canastota, N. Y., in 1927 and on which 23 claims were allowed by the Patent Office. Two of these engines, one of seven cylinders developing 180 hp. and the other of 14 cylinders developing 360 hp., were completed in 1929. In addition he designed and built a four-cylinder in-line aeronautic engine of 100 hp.

Mr. Hermann was elected to Member grade in the Society in November, 1929, and was a Buffalo Section member.

Personal Notes of the Members

Rickenbacker Decorated by President Hoover

America's highest military decoration was belatedly conferred upon Edward V. Rickenbacker on Nov. 6 at Bolling Field, District of Columbia, when President Hoover placed about his neck the blue ribbon of the Congressional Medal of Honor voted to him by the Congress for the American ace of aces' "conspicuous gallantry and intrepidity above and beyond the call of duty in action against the enemy near Billy, France, Sept. 25, 1918."

EDWARD V. RICKENBACKER

The conferring of the honor was witnessed by about 250 persons, among whom were nine of "Eddie's" former comrades of the 94th Aero Squadron in the World War and many eminent Government and Army representatives. Eighteen pilots constituting the new 94th Aero Squadron, who were attending high school at the time that Rickenbacker was performing the exploits at the front that won him his laurels, flew overhead during the conferring of the award. The First Observation Squadron, which is the oldest in the Army, and the 20th Bombardment Squadron passed in review before the assemblage. Major-Gen. James E. Fechet, chief of the Air Corps, who assisted the President, opened the ceremony by reading the Congressional citation and recalled that Colonel Rickenbacker already holds the Distinguished Service Cross and is credited with bringing down 21 enemy airplanes and 4 enemy balloons. He is now a colonel in the Reserve Corps. The citation reads in part:

While on a voluntary patrol over the lines, Lieutenant Rickenbacker attacked seven enemy planes (five type Fokker, protecting two type Halberstadt). Disregarding the odds against him, he dived on them and shot down one of the Fokkers out of control. He then attacked one of the Halberstadts and sent it down also.

Mr. Rickenbacker was elected to Member grade in the Society in 1928 and is a member of the Detroit Section. He officiated at the Metropolitan Aeronautic Meeting in New York City last May as Chairman of the Aircraft Design Session. He is now vice-president and director of sales of the Fokker Aircraft Corp. of America, with headquarters in New York City. He was born at Columbus, Ohio, in 1890 and began his automotive career in the engineering department of the Frayer-Miller Automobile Co., of Columbus, Ohio, in 1905. Two years later he joined the engineering department of the Columbus Buggy Co. and during the following 10 years was successively territorial representative of that company in Iowa and Nebraska, in charge of the Omaha branch, and engaged in automobile racing in conjunction with his sales work.

In 1917 Mr. Rickenbacker went overseas as chauffeur to General Pershing and subsequently was transferred to the 94th Aero Squadron, of which he became commander. He published a book in 1919 under the title, Fighting the Flying Circus. After the Armistice he returned to this Country and in 1921 formed the Rickenbacker Motor Co., of which he was elected vice-president. Five years later he joined the Detroit Aircraft Engine Works Syndicate as manager, and devoted his energies to developing five-cylinder air-cooled aircraft engines. His next connection was with the Cadillac Motor Car Co., of Detroit, which he joined in 1928 as assistant general sales manager in charge of sales of the LaSalle automobile. His present connection with the Fokker Aircraft Corp. was formed in July, 1929.

Whitten Joins Securities Company

Frank Allen Whitten, for the last two years chief engineer of the McCord Radiator & Mfg. Co., of Detroit, has accepted the post of engineering specialist in public utility securities with Bonbright & Co., in Detroit.

After concluding his engineering studies at the Rose Polytechnic Institute, Mr. Whitten formed a connection as draftsman with the Buckeye Engine Co., of Salem, Ohio, in 1898. At the end of that year he became engineer of tests for the Henry R. Worthington Co., of New York City, with which he remained for six years, engaged in steam, hydraulic and electric design, installation and sales work. In 1905 he joined the Lansden Co., of Newark, N. J., as engineer, superintendent and sales manager. Leaving that position in January, 1911, he joined the electric division of the General Motors Truck Co., in Pontiac, Mich. During the 15 years that he remained in the employment of the General Motors Truck Co. he rose to the position of chief engineer. Two years later Mr. Whitten entered the service of the American Car & Foundry Motors Co., doing engineering development and design work, and in 1928 was made chief engineer of that company. However, in 1929, he accepted the post of chief engineer of the McCord Radiator & Mfg. Co., of Detroit, with which he remained until his present association with Bonbright & Co.

Mr. Whitten's membership in the Society dates from 1912, and his very active participation in committee work dates from 1914, when he was made a member of the Electric Vehicle Division of the Standards Committee. He was a member of the Truck Division of the Standards Committee in 1918, its Vice-Chairman in 1921, and its Chairman in 1922 and again in 1928. He has also served as a member of the Springs Division of the Standards Committee since 1921. In 1922 he was appointed a member of the Highways Committee, and in 1926 was appointed Chairman of the Standards Committee and also a member of the Special Committee on Standardization Policy, on

FRANK ALLEN WHITTEN

which he served for two years. In 1928 he was appointed a member of the Motorcoach Division of the Standards Committee and also Chairman of the Motor-Truck Division of the Standards Committee.

Moskovics on Engineer's Opportunity

Some vigorously stimulating and encouraging thoughts addressed to automotive engineers are contained in two articles by Frederick E. Moskovics published in *Automotive Industries* for Nov. 8 and 15, 1930. These should richly repay any engineer for the expenditure of the few minutes required to read them. They would be inspirational and creative of an optimistic desire to do original thinking and designing even if they had been published anonymously. However, much weight and reason for giving them credence are contributed by the fact that they were written by a man of the judgment, ability and long experience possessed by Mr. Moskovics. The following quotations indicate the trend of his thoughts:

One division of the motor-car industry that has no cause for deploring the times is the engineering department. It can do more than any other single department to correct the economic evils that exist. Business distress has brought engineering opportunity.

In times like these the really constructive, creative engineer comes into his own. The gateway of the future swings open wider than ever in the past. His financial superiors will back him freely; his sales department will welcome his new ideas without calling them freaks; his production associates will give him assistance as never before.

In all the history of the automotive industry there never was a time when the formerly conservative financial heads of institutions would listen to "freak" ideas more eagerly than today; and never was there a greater demand for new things and new ideas than today.

And the best part of it all is, there never was a time when there were more original paths to tread, all leading to finer and better motor-cars.

No longer is there any doubt about the chance for the engineer; from here on it is a question of the engineer's ability to measure up to his chances. But there is every reason to believe that the engineers of the industry are either equipped or will equip themselves to meet this vital test.

I predict that technically the motor-vehicle will change more in the near future than in any like period of time in its history.

Know definitely what your collaborators in Europe have to teach you; interchange thoughts and ideas with them. The very lack of standardized thinking which has built up our great automobile industry is the charm over there. I have learned some very valuable lessons from my close contact with foreign engineers. Any engineer of good standing can easily establish these contacts. They will be immensely helpful to him and keep him posted on the progress of the art in that great laboratory of original research and development—Europe.

Mr. Moskovics entered the automobile industry almost at its beginning, when he became connected with the Daimler company in Europe. In the following 30 years he has been identified with the selling, designing and manufacturing of tires, cars and parts in this

FREDERICK E. MOSKOVICS

Country, successively with the Continental Tire Co., Brandenburg Brothers, the Kingston Motor Car Co., the Remy Electric Co., the Nordyke & Marmon Co., the Franklin Automobile Co. and the Stutz Motor Car Co. A little more than a year ago he resigned the presidency of the Stutz company to assume the presidency of the newly formed Improved Products Corp., of New York City, organized as an investment banking institution.

Mr. Moskovics has been a very active Member of the Society since 1908, having served as Councilor, on the Meetings Committee, in 1928 as Chairman of the Constitution Reorganization Committee, as Chairman of the House Committee and on the S.A.E. Simplified Practice Committee. He has been an active member also of the Metropolitan and Indiana Sections, and has presented a number of valuable technical papers at meetings of the Society.

Roy F. Anderson has severed his connection with the Hayes Body Corp., of Grand Rapids, Mich., as vice-president in charge of engineering, and is now connected with the Murray Corp. of America, of Detroit, in the capacity of sales engineer.

Harold M. Baker, who had been studying at the Massachusetts Institute of Technology, in Cambridge, Mass., is now an assistant in mechanical engineering at that institution.

Oscar C. Bornholt, former president of the Oakes Products Corp., of North Chicago, is now serving the Houdaille-Hershey Corp., of Chicago, as research engineer.

Elliott Daland, previously an engineer with the Keystone Aircraft Corp., of Bristol, Pa., is now serving the Kellett Aircraft Corp., of Philadelphia, in a similar capacity.

Elbert Denninger, a former student engineer at the International Motor Co., of Allentown, Pa., is now studying at the Rensselaer Polytechnic Institute, at Troy, N. Y.

Having relinquished his position as experimental engineer with the Wilkening Mfg. Co., of Philadelphia, **N. E. Drulet** is now sales manager and engineer for the Budlong & Funchess Motor Products Co., of Hanford, Calif.

William W. Dunnell, Jr., having severed his connection with Comstock & Westcott, Inc., of Cambridge, Mass., as production engineer, is now employed in the capacity of machine designer by the Reece Buttonhole Machine Co., of Boston.

John J. Grabfield, who lately relinquished his post as project engineer in the General Motors Research Laboratory, in Detroit, recently accepted a position as test engineer with the Hudson Motor Car Co., also of Detroit.

Pienchun Huang, a former student at Purdue University, is now studying at the Massachusetts Institute of Technology, in Cambridge, Mass.

H. A. Huebotter, who has been serving the Waukesha Motor Co., of Waukesha, Wis., as a research engineer, has recently assumed the duties of instructor in automotive engineering for the General Motors Institute of Technology, at Flint, Mich.

J. J. Hughes has been transferred from the Dayton, Ohio, branch of the Mack International Motor Truck Corp., where he was service manager, to the Chicago branch, where he will assume the duties of shop superintendent.

Announcement has been made that the activities of the engineering departments of the Brockway and Indiana divisions of the Brockway Motor Truck Corp. have been concentrated at Cortland, N. Y., and that **M. L. Kerr**, who joined the Indiana Truck Corp., at Marion, Ind., as chief engineer, is now chief engineer for the combined organizations.

Frederick Knack has resigned his position as secretary for Aerotach, Inc., of Moline, Ill., and is now serving the Mono Aircraft Corp., also of Moline, as chief engineer.

Konrad Langer has left the employment of the Brooks Steam Motors, Inc., of Buffalo, with which he was a designer, and has become a layout draftsman for the Curtiss Aeroplane & Motor Co., also of Buffalo.

(*Continued on p.* 50)

Applicants Qualified

The following applicants have qualified for admission to the Society between Oct. 10 and Nov. 10, 1930. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

AVERY, IRVING F. (M) chief engineer, Jacob Press Sons, *Chicago;* (mail) 3215 Normal Avenue.

BAHN, STEN HJORTSOE (J) sales student, International Harvester Co., Chicago; (mail) 137 North Limestone Street, *Springfield, Ohio.*

BARBOUR, ROBERT YALDING (J) structural engineer, Lord & Burnham Co., Irvington, N. J.; (mail) 127 Harwood Avenue, *Philipse Manor, N. Y.*

BARCLAY, STANTON D. (M) instructor, Pratt Institute, 215 Ryerson Street, *Brooklyn, N. Y.*

BEACH, RUSSELL S. (A) lubricating engineer, Fiske Bros. Refining Co., Toledo, Ohio; (mail) 3-258 General Motors Building, *Detroit.*

BEALE, HORACE A., 3RD (A) *Parkersburg, Pa.*

BOWEN, H. C. (M) research engineer, Hydraulic Brake Co., 2843 East Grand Boulevard, *Detroit.*

BRUN, ANDREW (A) draftsman, Sikorsky Aviation Co., *Stratford, Conn.;* (mail) 2572 Main Street.

COLVIN, HENRY F. (M) vice-president, Pioneer Instrument Co., Brooklyn, N. Y.; (mail) 218 Conway Court, *South Orange, N. J.*

DORNIER, CLAUDE, DR. (F M) engineer, Dornier Metallbauten G.m.b.H., Friedrichshafen, Germany; (mail) *Friedrichshafen, Bodensee, Germany.*

DOXSEY, WALTER S. (A) publisher, *Automotive Abstracts*, Penton Publishing Co., Penton Building, *Cleveland.*

ENGEL, WILLIAM F. (A) mechanical draftsman, Hercules Motors Corp., *Canton, Ohio;* (mail) 920 13th Street, North East.

EVANS, EDWIN R. (M) engineer, brake division, Stewart-Warner Corp., *Chicago;* (mail) Belden Stratford Hotel.

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HAGAN, ALBERT W. (M) chief engineer, Wolverine Motor Works, Inc., *Bridgeport, Conn.;* (mail) 95 Waterman Street.

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HOWIE, HOWARD N. (J) 46-23 Sixth Avenue, *Brooklyn, N. Y.*

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JEWETT, FREDERIC D. (J) chief, mathematics section, Keystone Aircraft Corp., *Bristol, Pa.;* (mail) 817 Radcliffe Street.

JONES, EDWARD A. (J) service manager, Yellow Cab Co. of Virginia, Inc., *Richmond, Va.;* (mail) 204c Minor Street.

KAYSER, HAROLD J. (J) general foreman, William Armstrong Publishing Co., Inc., New York City; (mail) *Lindenhurst, L. I., N. Y.*

KERR, HENRY HAMPTON, JR. (M) sales engineer, airplane products, Bendix Brake Co., *South Bend, Ind.*

KRIEGER, CARL G., JR. (J) sales engineer, Ethyl Gasoline Corp., New York City; (mail) care Ethyl Gasoline Corp., 1004 Court Square Building, *Baltimore.*

LEONARD, LLOYD HUGO (J) aeronautical engineer, research department, Edward G. Budd Mfg. Co., *Philadelphia;* (mail) 41 West Logan Street.

MAYO, WILLIAM N. (A) sales manager, Farfall Co., 5680 12th Street, *Detroit;* (mail) 1130 Parker Avenue.

MEISTER, REGINALD E. B. (A) research engineer, Duplex Motor, Inc., Everett, Mass.; (mail) 208 White Street, *Belmont, Mass.*

MESTON, ALECK W. (A) experimental engineer, Moto Meter Gauge & Equipment Corp., *Toledo, Ohio;* (mail) Hillcrest Arms Apartments, 16th and Madison Streets.

MILLS, RICHARD M. (A) manager, dining-car sales department, J. G. Brill Co., Philadelphia; (mail) 927 Church Lane, *Yeadon, Pa.*

MORRISON, A. T. (A) assistant service manager, Stutz Chicago Factory Branch, Inc., 2500 South Michigan Avenue, *Chicago.*

NESS, MARTIN A. (A) district manager, Canton Drop Forging & Mfg. Co., New York City; (mail) 262 North Grove Street, *East Orange, N. J.*

NEULAND, ALFONS H. (M) president, in charge of development, Electro-Mobile Corp., 227 Coit Street, *Irvington, N. J.*

ORMSBY, EDMUND B. W. (J) detail draftsman, aeronautical, Naval Aircraft Factory, United States Navy Yard, *Philadelphia.*

PENDLETON, PHILIP E. (M) aeronautical engineer, weight department, B/J Aircraft Corp., Dundalk, *Baltimore;* (mail) Box 10.

ROESCH, J. ALBERT, JR. (A) president, Steel Sales Corp., 129 South Jefferson Street, *Chicago.*

ROSS, WILLIAM BYRON (M) member research committee, Vacuum Oil Co., 61 Broadway, *New York City.*

SANG, HENRY JAMES (J) junior engineer, Naval Aircraft Factory, United States Navy Yard, Philadelphia; (mail) 409 Pembroke Road, *Bala-Cynwyd, Montgomery County, Pa.*

SCHAEFER, JOHN (M) superintendent of transportation, Adolf Goebel, Inc., Morgan Avenue and Rock Street, *Brooklyn, N. Y.*

SEAGREN, JOHN (M) engineer, research department, Fairbanks, Morse & Co., *Beloit, Wis.;* (mail) 1220 Emerson Street.

SHEREDA, LOUIS JOHN (J) draftsman, Ford Motor Co., Dearborn, Mich.; (mail) 7755 Hendrie Avenue, *Detroit.*

SULLIVAN, EVERRARD J. (M) manager, Ajax Auto Parts Co., 15th Street and C. & N. W. Tracks, *Racine, Wis.*

WELLINGTON, FRANK E. (M) manager, aviation division, Wyman-Gordon Co., 105 Madison Street, *Worcester, Mass.*

WINEGARD, E. W. (J) body engineer, designer, Whitfield & Sons, Inc., *Penn Yan, N. Y.;* (mail) Box 323.

ZERBI, TRANQUILLO (F M) main technical director, F I A T, via Nizza 250, *Turin, Italy.*

Applicants for Membership

The applications for membership received between Oct. 15 and Nov. 15, 1930, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ATWOOD, SETH B., partner, Atwood Vacuum Machine Co., *Rockford, Ill.*

BAESE, DR. WALTER K. F., research engineer, International Motor Co., *Allentown, Pa.*

BEST, ROBERT D., junior engineer, Bureau of Standards, *City of Washington.*

BOCKSRUKER, AL. F., draftsman, Allis-Chalmers Mfg. Co., *Milwaukee.*

CAHILL, J. C., district manager, Brockway Motor Truck Corp., *Cortland, N. Y.*

CASSADY, G. H., tire-design engineer, United States Rubber Co., *Detroit.*

CHAPPELL, FRANK, factory manager, General Motors of Canada, Ltd., *Oshawa, Ont., Canada.*

CIVILETTO, PHILIP, service attendant, Midwest Motors, Inc., *St. Louis.*

CLINE, M. W., president, Dart Truck Co., *Kansas City, Mo.*

COHEN, MORRIS, industrial engineer, *Kansas City, Mo.*

CONDAK, EDWARD, layout draftsman, Chevrolet Motor Co., *Detroit.*

CURRO, FRANK CARL, 938 43rd Street, *Brooklyn, N. Y.*

DAVIS, W. RALPH, sales and transportation engineer, The White Co., *Houston, Texas.*

DEY, ANTHONY ROBERT, production engineer, Kimball Aircraft Corp., *Naugatuck, Conn.*

DUTTERER, REX J. L., engineer, Defiance Spark Plugs, Inc., *Toledo, Ohio.*

FALES, ELISHA N., aeronautical engineer, Aviation Corp., *New York City.*

GODFREY, EDWIN H., project engineer, Wright Aeronautical Corp., *Paterson, N. J.*

GROSNY, FRIDRICH G., experimental engineer, Autostroy, Ford Motor Co., *Dearborn, Mich.*

HARDY, EVAN A., professor of agricultural engineering, University of Saskatchewan, *Saskatoon, Sask., Canada.*

HENCKEL, JOACHIM, experimental engineer, Chrysler Corp., *Detroit.*

HULL, GEORGE E., vice-president, general manager, Parks & Hull, Inc., *Baltimore.*

JEWETT, DANIEL G., superintendent of maintenance, L. Bamberger & Co., *Newark, N. J.*

JOHNSON, GUNNER, experimental engineer, Motor Improvements, Inc., *Newark, N. J.*

JONES, OSCAR BERNARD, president, Detroit School of Applied Science, *Detroit.*

KASS, CHARLES B., Mechanical engineer, Standard Oil Development Co., *Linden, N. J.*

KING, DUDLEY S., Draftsman, Lycoming Mfg. Co., *Williamsport, Pa.*

KINGSLAND, SIDNEY AUGUSTUS, 3801 Avenue I, *Brooklyn, N. Y.*

KIRKLAND, ARTHUR, manufacturing representative and designing engineer, Kirkland Sales & Engineering Co., *Detroit.*

LABRIE, LUDGER ELIZE, designing engineer, Bendix Brake Co., *South Bend, Ind.*

LAGER, E. W., manager automobile division, Swift & Co., *Chicago.*

LAPP, JOHN, district superintendent of automotive equipment division, Public Service Corp., *Newark, N. J.*

LECHER, EARLE A., layout man, Wisconsin Motor Co., *Milwaukee.*

LIPGART, ANDREY, designer, Ford Motor Co., *Dearborn, Mich.*

LOVESETH, ENOCH L., manager and owner, Loveseth Service Station, Ltd., *Edmonton, Alberta, Canada.*

LYSAGHT, VINCENT E., engineer, Wilson Maevlen Co., *New York City.*

MAGEE, C. L. C., member of firm, Magee Pfeiffer Co., *Chicago.*

MANNING, NEWTON H., general manager, Le Baron Detroit Co., *Detroit.*

MARSHALL, BROOKS, representative of new devices committee, General Motors Corp., *Detroit.*

MAW, FREDERICK ARTHUR L., chief engineer, Vacuum Oil Co. Proprietary, Ltd., *Melbourne, Australia.*

MCCARTY, D. W., owner, Mother Lode Garage, *San Andreas, Calif.*

MEATZE, BRITTON, assistant foreman, Cadillac Motor Car Co., *Detroit.*

MILLER, CLINTON E., service manager, The White Co., *Utica, N. Y.*

MOLLINGER, ALEXANDER, lecturer for internal-combustion engines, University of Delft, *Delft, Holland.*

MORRISON, JOHN, service manager, automobile Clearing House, Ltd., *Saskatoon, Sask., Canada.*

NORQUIST, VICTOR C., plant engineer, Butler Mfg. Co., *Kansas City, Mo.*

ONGARO, TEDDY, owner and manager, Teddy's Auto Service Station, *Columbus, Ohio.*

PATTERSON, ROBERT B., dynamometer helper in experimental department, Continental Motors Corp., *Detroit.*

PURDY, FRED H., special sales representative, J. J. Hart, *Brooklyn, N. Y.*

RABINOWITZ, SAMUEL, student, Institution of Aeronautics, *New York City.*

RAUCH, JOHN DODDS, chief engineer, Ohio Power Shovel Co., *Lima, Ohio.*

RELPH, WILLIAM, shop foreman, Imperial Motors, Ltd., *Calgary, Alberta, Canada*

RENNELL, HENRY H., secretary and general manager, C. O. Jelliff Mfg. Co., *Southport, Conn.*

RICHARDSON, RALPH A., engineer, technical data section, General Motors Corp. Research Laboratories, *Detroit.*

RITCHIE, DANIEL F., equipment sales engineer, tractor division, Allis-Chalmers Mfg. Co., *Springfield, Ill.*

RIX, JOHN WILTON, factory manager and assistant chief engineer, Martin Motor Truck Co., *Garden City, N. Y.*

ROBERTSON, DELMAR D., engineer, Wilkening Mfg. Co., *Philadelphia.*

ROBIE, CHARLES F., student in master-pilot course, Boeing School of Aeronautics, Oakland Airport, *Oakland, Calif.*

ROSE, L. F., designer, draftsman, Box 565, Grand Central Station, *New York City.*

SCHNEIDER, HEINRICH, technical research engineer, Fairbanks, Morse & Co., *Beloit, Wis.*

SEMRAD, R. Q., president, Cleveland Ignition Co., *Cleveland.*

SHEELEY, C. FRANK, chief tool designer, Hyatt Roller Bearing Co., *Harrison, N. J.*

SIEVERT, WILLIAM H., JR., field representative, Ethyl Gasoline Corp., *Los Angeles.*

SMITH, DALE, draftsman, Stearman Aircraft Co., *Wichita, Kan.*

SMITH, PAUL J., body engineer, mechanical division, Cadillac Motor Co., *Detroit.*

SPALDING, F., time-study engineer, J. I. Case Co., *Rockford, Ill.*

TATTERSALL, NORMAN, draftsman, Leyland Motors, Ltd., *Leyland, England.*

THATCHER, CHARLES G., associate professor, mechanical engineering, Swarthmore College, *Swarthmore, Pa.*

THOMAS, WILEY, H., branch engineer, Vacuum Oil Co., *Houston, Texas.*

TOPPING, JOSEPH, draftsman, Smith Engineering Co., *Cleveland.*

TYLER, JOHN M., research engineer, General Motors Corp., Research Laboratories, *Detroit.*

VAHEY, STANLEY C., designer, Chevrolet Motor Car Co., *Detroit.*

VYFF, POUL, detailer, Chevrolet Motor Co., *Detroit.*

WELLENKAMP, PAUL G., 9 Burnham Place, *Fairlawn, N. J.*

WYNNE, CHARLES HORACE LIONEL, chief engineer, Stromberg Motor Devices, Ltd., *London, England.*

YACE, ANTHONY V., president and general manager, New Canaan Garage & Motor Sales Co., *Springdale, Conn.*

ZETWICK, JOSEPH L., detail draftsman, Quimbly Pump Co., Newark, N. J.

Notes and Reviews

AIRCRAFT

Full-Scale Wind-Tunnel Tests of a Propeller with the Diameter Changed by Cutting Off the Blade Tips. By Donald H. Wood. Report No. 351. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 25 pp. [A-1]

Tests were conducted to determine how the characteristics of a propeller are affected by cutting off the tips. The diameter of a standard 10-ft. metal propeller was changed successively to 9 ft. 6 in., 9 ft. 0 in., 8 ft. 6 in., and 8 ft. 0 in. Each propeller thus formed was tested at four pitch-settings in the propeller research tunnel of the National Advisory Committee for Aeronautics, using an open-cockpit fuselage and a D-12 engine.

A small loss in propulsive efficiency is indicated. Examples are given showing the application of the results to practical problems.

Comparative Flight Performance with an N.A.C.A. Roots Supercharger and a Turbocentrifugal Supercharger. By Oscar W. Schey and Alfred W. Young. Report No. 355. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 14 pp. [A-1]

As there are now several types of superchargers in service, information on the comparative performance obtained with each type would be of value in the selection of a supercharger to meet definite service requirements. As a part of the program to obtain this information, the National Advisory Committee for Aeronautics conducted tests, using a modified DH-4M2 airplane with a turbocentrifugal and with a Roots-type supercharger. The rate of climb and the high speed in level flight of the airplane were obtained for each supercharger from sea level to the ceiling. The unsupercharged performance with each supercharger mounted in place was also determined.

The results of these tests show that the ceiling and rate of climb obtained were nearly the same for both superchargers, but that the high speed obtained with the turbocentrifugal was better than that obtained with the Roots. The high-speed performance at 21,000 ft. was 122 and 142 m.p.h. for the Roots and turbocentrifugal, respectively.

An Accurate Method of Measuring the Moments of Inertia of Airplanes. By M. P. Miller. Technical Note No. 351. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 20 pp., 7 figures. [A-1]

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor, *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

This note is a description of the improved apparatus and procedure used by the National Advisory Committee for Aeronautics for determining the moments of inertia of airplanes. The method used involves swinging the airplane body as a pendulum. In previous tests secondary oscillations seriously affected the accuracy of the results, but the apparatus here described has been carefully designed to eliminate the errors. These tests show that the accuracy attained is satisfactory.

Analytical Determination of the Load on a Trailing-Edge Flap. By Robert M. Pinkerton. Technical Note No. 353. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 7 pp.; 2 figures. [A-1]

This report presents a theoretical analysis of the lift on a trailing-edge flap. An analytical expression has been derived which enables the computation of the flap load-coefficient. The theoretical results seem to show a fair agreement with the meager experimental results that are available.

Counter-Propeller. By Ugo de Caria. Translated from *Aeronautica*, June, 1930. Technical Memorandum No. 587; 11 pp., 6 figures. [A-1]

Diesel-Chamber Investigations. Ignition-Chamber Engines. By Kurt Neumann. Translated from *Dieselmaschinen* IV, 1929. Technical Memorandum No. 589; 30 pp., 10 figures. [A-1]

Velocity Distribution in the Boundary Layer of a Submerged Plate. Translated from *Abhandlungen aus dem Aerodynamischen Institut der Technischen Hochschule Aachen*, No. 8, 1928. Technical Memorandum No. 585; 18 pp., 24 figures. [A-1]

Göttingen Six-Component Scale Measurements on a Junkers A-35 Airplane Model. By Herman Blenk. Translated from *Jahrbuch* 1930 *der Deutschen Versuchsanstalt für Luftfahrt.* Technical Memorandum No. 586; 8 pp., 15 figures. [A-1]

The Behm Acoustic Sounder for Airplanes, with Reference to Its Accuracy. By Ernest Schreiber. Translated from *Jahrbuch* 1930 *der Deutschen Versuchsanstalt für Luftfahrt.* Technical Memorandum No. 588; 18 pp., 12 figures. [A-1]

The foregoing Technical Memoranda were issued during the month of October by the National Advisory Committee for Aeronautics, City of Washington.

The Parasite Drag of Airplane Tires. By C. H. Martens. Published in *Aviation Engineering*, October, 1930, p. 9. [A-1]

Extensive investigations have recently been carried out in the wind tunnel of the New York University to obtain data on the drag characteristics of several types of airplane tires, to aid in the development of a line of airplane tires of low specific resistance.

It was found that the parasitic drag of the low-pressure airplane tires tested was not appreciably greater than that of the high-pressure airplane tires in the same load-carrying class. These tests indicate that accurate airplane performance calculations cannot be made if an average drag coefficient is used for all sizes and types of airplane tires.

Tank Tests with Seaplane Models. By R. J. Mitchell. Published in *Aircraft Engineering*, October, 1930, p. 255. [A-1]

The tests reported herein and the test models used are described in detail and illustrated with charts and drawings. The author is of the opinion that the data obtained from tank tests can be used as a sound and reliable basis upon which to carry out or develop the design of marine aircraft along the most economical and efficient lines.

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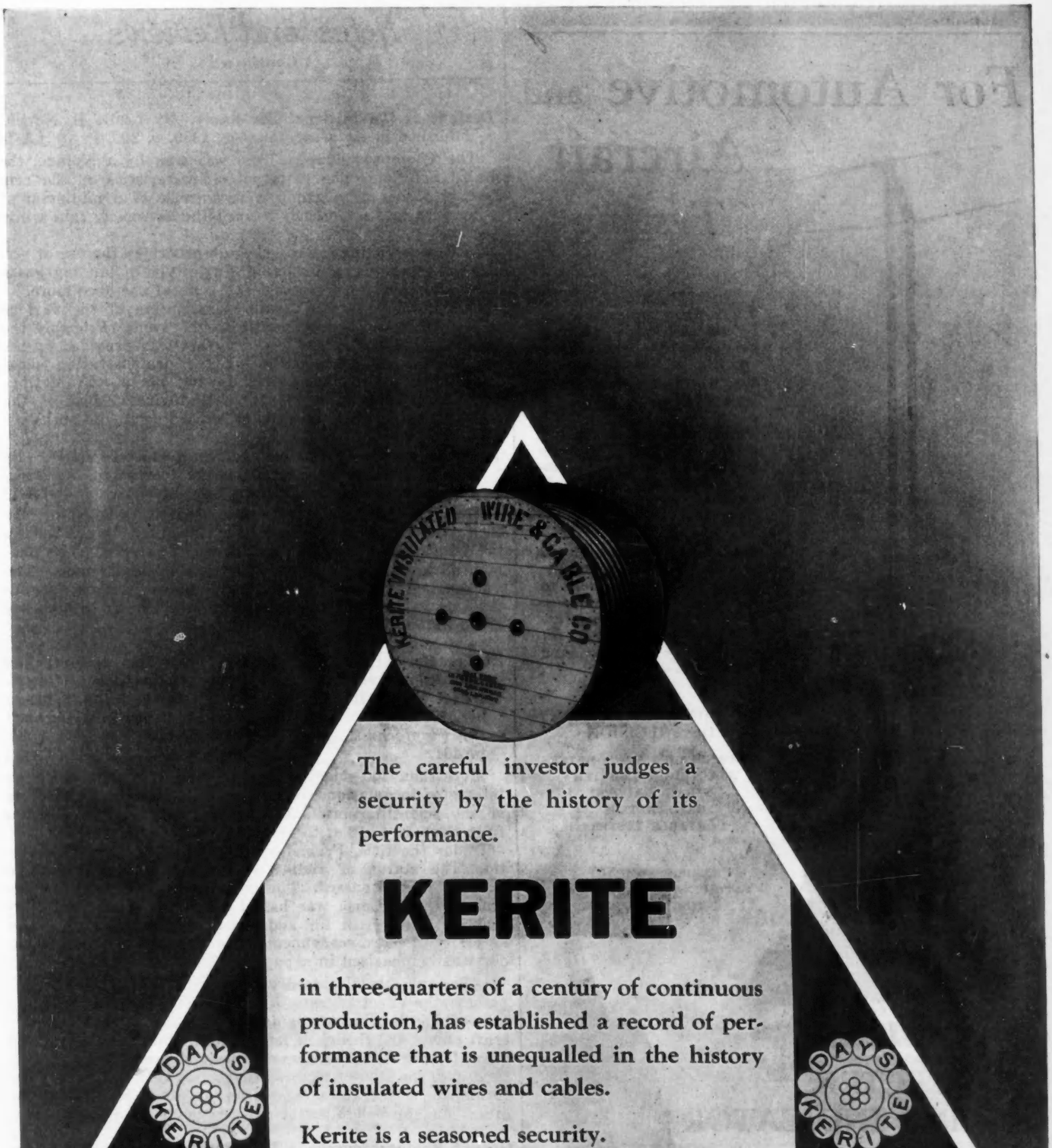
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Notes and Reviews

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Designs at the National Air Races. By Leslie E. Neville. Published in *Aviation*, October, 1930, p. 209. [A-1]

The Thompson Trophy Race was won by a biplane, the Laird Solution. The principal characteristics of the contesting planes as a group were the use of a minimum of wing area and a tendency toward the extremely thin wing-section.

With the elimination of shock-absorbers by the use of air-wheels, the old cross or straight-axle type of landing gears has a fair chance of coming into general use once more.

The author gives a detailed description of the various types of airplane participating in the event. Probably the most interesting part of the program was provided by the group of airplanes constituting the demonstration class, notably the Waterman variable-wing plane, the McDonnell Doodle Bug, and the three Autogiros. Most of the designs showed little originality, according to the author.

A Study of the Phenomenon of Spin in Aeroplanes. By H. E. Wimperis. Published in *The Journal of the Royal Aeronautical Society*, October, 1930, p. 872. [A-1]

The author first describes what constitutes a spin. He then gives in detail the nature of the forces which act on the wings of an airplane and cause it to spin. The phenomena are highly complex and not fully understood. The various tests made with models by different research organizations in England, Germany and the United States are given in detail.

Kurzer Bericht über den Verlauf der XIX. Ordentlichen Mitgliederversammlung der Wissenschaftlichen Gesellschaft für Luftfahrt E.V. (WGL) vom 10. bis 13. September, 1930. By Victor Garganico. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Sept. 29, 1930, p. 461. [A-1]

More than 300 scientists, government officials and others interested in aviation gathered at the 19th regular meeting of the scientific aeronautical association held in Breslau from Sept. 10 to 13 of this year.

Under the title, Problems and Aims of Safety in Aviation, the status of radio, weather service and airways lighting was discussed. The development work of the Detroit Aircraft Corp. was hailed as a new step in heavier-than-air history in an address on metal airships. The necessity of more economical and suitable production methods was emphasized in a paper devoted to this topic.

Other subjects discussed were: records in aviation; compasses; the effect of rarefied atmosphere on heart action; take-off and landing of seaplanes; torsional strength of aircraft parts; the theory of longitudinal stability of aircraft; aircraft brakes; carbureter engines and comparisons of this type with the Diesel engines; fuel tests; resistance and performance of radiators; the drag of air-cooled radial engines; and propeller performance, calculated and actual.

Optisch-Photographische Formänderungsmessungen an Luftfahrzeugen. By Hans Georg Küssner. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Sept. 15, 1930, p. 433. [A-1]

Apparatus for the study of the deformation of wing truss and other aircraft structures in flight is here described, and results obtained through its use are briefly summarized.

The method used consists in illuminating a series of points on the part to be studied and photographing the varying positions of these under deformation on a roll of sensitive paper, which runs continuously at a constant, regulated speed.

The importance of obtaining information on the dynamic stressing of aircraft parts is emphasized, as well as the advantages of the photographic method. The apparatus

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is described, as is also its use for the following purposes: measurement of the deformation of the wings of the DO-X flying boat, and of the wings of the transport airplane G-24; determination of the best type of bracing for the DO-X flying boat; comparison of the relative damping characteristics of pine and spruce; and research on fatigue in a steel spar.

Final Report of the Daniel Guggenheim Fund for the Promotion of Aeronautics, 1929. [A-3]

This Fund liquidated its affairs on Feb. 1, 1930. Its purpose had been to promote aeronautical education throughout the Country, to assist in the extension of aeronautical science, and to further the development of commercial aircraft, particularly in its use as a means of transportation for both goods and people.

To prove to the general public that travel by air was safe, the Fund financed airplane tours by Floyd Bennett and Col. Charles A. Lindbergh. It stimulated the development of aeronautic research and instruction by establishing aeronautic engineering centers in various parts of this Country and giving financial aid to aero clubs in Europe. In addition, it aided the development of the model weather-reporting service, roof marking, study of fog-flying, and aircraft safety.

A. B. C. of Gliding and Sailflying. Edited by Major Victor W. Page. Published by the Norman W. Henley Publishing Co., New York City, 1930; pp. 283 and index. Price, $2. [A-3]

This treatise contains a brief history of gliding and soaring with motorless airplanes and an interesting study of bird flight and its relation to the principles underlying static and dynamic sailflying.

Popular German and American gliders and soaring planes are described and illustrated. Structural elements and materials for construction are fully considered and typical designs are outlined in detail.

The book also contains practical instructions for forming glider clubs, the selection of terrain for gliding, and methods of launching and flying gliders and soaring planes incidental to the training of pilots.

The Aviation Industry. By the division of commercial research of the Curtis Publishing Co., Philadelphia; 176 pages. [A-3]

This report is a compilation of impressions gathered by representatives of the Curtis company's division of commercial research from interviews with and the cooperation of manufacturers, distributors, airport managers, and other leaders in aviation in various parts of the Country. It is a study of the underlying trends and inherent peculiarities of the industry.

Ten Years' Gliding and Soaring in Germany. By D. Walter Georgii, of Darmstadt. Published in *The Journal of the Royal Aeronautical Society*, September, 1930, p. 725. [A-3]

The restrictions of the Versailles Treaty turned the air-minded members of the younger generation of Germany toward gliding as a substitute for power flight; thus gliding and soaring, after ten years of popularity, are rapidly acquiring the proportions of a national sport in that country.

Modern scientific construction and meterological knowledge have made possible a soaring record of over 14-hr. duration and a sailplane altitude record of 2500 ft. above the starting point.

Dr. Georgii has related the historical development of the glider society and the achievement of an unbroken series of ten gliding competitions held at Wasserkuppe. In addi-

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tion, he describes the standard gliders and the records that have been made with each.

He gives detailed illustrations, in the form of barograms and photographs, of the difference between hill and cloud flying; between flying from hill to hill over a course which must be adjusted to the contours of the ground, and flying from cloud to cloud over hill and plain when the ground is ignored and the pilot must scan the cloud formations and adjust his course to their motion.

The union of sport and science will give the new generation of fliers a body of weather wisdom by which they may safely meet and even turn to useful purpose the atmospheric disturbances so frequently met with in air transport today.

Airport Problems of American Cities. By Austin F. MacDonald. Reprint from *The Annals of the American Academy of Political and Social Science*, Philadelphia, 1930. Price, $1. [A-4]

Within the last few years cities, civic and commercial groups have become conscious of the need for suitable air-terminal facilities, until now there are approximately 1600 airports in the United States.

The author discusses airports of today and tomorrow; their size, location, and essential characteristics; also the work of the aeronautical branch of the Department of Commerce.

CHASSIS PARTS

Power Application to Oscillating Axles. By Alian Madlé. Paper presented at the semi-annual meeting of the American Society of Mechanical Engineers, Detroit, June 9 to 12, 1930. [C-1]

In this paper the author describes the type of axle in which the load is not carried by the wheel center but is suspended at the end of an arm which is permitted to swing like a pendulum about the wheel center. This mechanism is called a differential drive, and its application to motor-driven vehicles is described. The forces acting in the mechanism and the conditions necessary for an equilibrium of forces are worked out mathematically, and a comparison is given of starting motor-trucks by two systems: first, when equipped with an oscillating axle with differential drive, and, second, with the usual method of drive.

By means of the differential drive it is claimed that torque can be applied momentarily to the wheel without turning it, and that an elastic connection is provided between the power line and the wheel which cushions torsional impacts. Whenever there are changes in the running conditions of the vehicle, fluctuations of energy between the wheel assembly and the vehicle body occur. The reaction forces of these fluctuations provide an increased pressure against the ground, an additional accelerating force and a greater retarding force.

Factors that Influence the Successful Operation of Bus Springs. By N. E. Hendrickson. Published in *Bus Transportation*, October, 1930, p. 556, [C-1]

Leaf springs, in addition to carrying loads, act as radius-rods for the axles, points out the author. The rear springs also act as torque members, and now, with four-wheel brakes, the front springs are taking torque reactions.

If springs are to protect the motorcoach and its passengers from road shocks, it is very essential that they be correctly designed with regard to flexibility and stress. The material used should respond to accurate heat-treatment and develop resistance to failure from repeated vibrations. These properties should be combined with extremely high strength.

The author is opposed to replacing broken leaves, because if one leaf breaks it is evidence that all the leaves

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are fatigued. In such a case the logical thing is to replace with a complete new spring.[4]

A Propos de Quelques Résultats Expérimentaux sur le Freinage. By Henri Petit. Published in the *Journal de la Société des Ingénieurs de l'Automobile,* August, September, October, 1930, p. 1106. **[C-1]**

The maximum negative acceleration, or deceleration, that can be expected in a passenger-car the brakes of which are in perfect condition and correctly adjusted is from 7 to 8 m. per sec. (22 ft. 11 in. to 26 ft. 6 in.). For ordinary cars in normal operation, the brake performance is about one-half the maximum. These conclusions are drawn by the author in the course of this account of public brake-tests recently conducted under his supervision.

For the purpose of this competition, braking performance was calculated from the speed of the vehicle at the time of brake application and the stopping distance, both of these factors being measured by methods described. Although this procedure is admittedly open to criticism on the ground of inaccuracy, it was adopted as more suitable for a public demonstration than the more accurate measurement by recording accelerometer. The calculations made are based on the assumption that the negative acceleration is constant throughout the braking period, an assumption that is said to have been substantially confirmed by preliminary accelerometer measurements, the results of which are given.

In addition to presenting the results of the tests, the author gives braking curves based on certain supplementary measurements, tending to show the effect of the degree of wetness of the road surface, of a servo mechanism, of the front brakes alone and the rear brakes alone, and of the engine as a brake. Curves showing the acceleration of a vehicle in the three forward speeds are also given.

ENGINES

The Resistance of Air-Cooled Engines. By Major F. M. Green. Published in *The Journal of the Royal Aeronautical Society,* October, 1930, p. 803. **[E-1]**

Cooling and drag are inseparably bound up with each other. The horsepower that has to be transferred to the cooling air does not depend upon arrangement of the cylinders, but upon provision that is made for the air to flow around the cylinder-heads and barrels.

The research upon which this paper is based was concerned with the drag of a radial engine in conjunction with carrying pilot and passenger, and the drag of an isolated power unit. Tests were made on models in considerable detail in the wind tunnel at the Sir W. G. Armstrong Whitworth Aircraft Works.

Various experiments were made with cowling, spinner, and other drag reducers, but the best results were obtained with the use of a Townend ring, which reduced the drag of the body plus engine to just over 30 lb.

Linear Inertia Force of Connecting-Rod Resolved into Two Components. By M. W. Davidson. Published in *Automotive Industries,* Oct. 4, 1930, p. 479. **[E-1]**

In this study of the connecting-rod, the author found that (*a*) the effect of the inertia of the reciprocating weights results in a torque on the frame equal and opposite to that on the crank, together with an axial force through the main bearing equal to that required for the acceleration of these weights; (*b*) the slight effect produced by the weight of the piston and connecting-rod is similar to that produced on the frame and crank by the reciprocating-weight inertia force and the axial component of the force for the linear acceleration of the rod; and (*c*) the effect of the fluid pressure on crank and frame respectively is that of equal and opposite couples, together with equal and

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opposite axial forces on the frame at the cylinder head and the main bearing.

Therefore, it would seem that only when the inertia effects are in balance does the variation of the crank torque represent the vibratory condition of the engine.

The Influence of Turbulence upon Highest Useful Compression Ratio in Petrol Engines. By T. F. Hurley and R. Cook. Published in *Engineering*, Sept. 5, 1930, p. 290. **[E-1]**

An E-5 Ricardo variable-compression engine was used for the tests herein reported. The method employed to give the desired direction to the air as it entered the cylinder was to insert in the ports, as close to the sleeve as possible, groups of directional vanes consisting of thin, curved, parallel plates.

The authors found that drops of water revolved more quickly near the central axis than farther out, which seems to indicate that the swirling motion of the charge is free vortex motion and not a forced vortex, as is sometimes assumed.

With indiscriminate turbulence, it was found that both the oil and water tended to collect at definite nuclei, the position of which depended on the vane arrangement and depth of combustion-chamber, but no spiral movement was observable. The experiments show, that when a swirling motion is set up, the pressure is least and the linear velocity greatest near the center.

Although these experiments do not definitely show the presence of inward radial flow, as in a free spiral vortex, they do suggest the occurrence of inward radial flow near the surface of the head and piston.

If the theory derived from the results of the tests for the H.U.C.R. of a standard fuel with various conditions of turbulence is correct, it should give rise to a new tendency in combustion-chamber design that would enable a high compression-ratio to be used without detonation.

De la Conjugaison des Qualités des Carburants et des Moteurs à Explosion. By M. A. Grebel. Extract from the *Mémoires de la Société des Ingénieurs Civils de France*, January-February, 1930; 144 pp.; 34 illustrations. **[E-1]**

In attacking the comprehensive subject of the adaptation of engine to fuel and fuel to engine, the author addresses himself to both engine designer and petroleum refiner, as only by the cooperation of the automotive and oil industries can the more efficient utilization of fuel in internal-combustion engines be brought about. His subject matter consists, not of a general treatise of all phases of the subject, but of deductions drawn from his own experiments and reflections, in a setting of more widely known fundamentals.

The problems of the carbureter-charged electric-ignition engine, the Diesel and the semi-Diesel engine are considered. The first chapter deals with engines, and in it the essential differences between the three types are first pointed out. Next treated is the transformation of the potential energy in the cylinder to effective torque, in connection with which the optimum speed of combustion is considered as a major point. An analysis is made of thermal efficiency, with particular attention to the influence of compression pressure and the limitations placed on it by knocking.

In the second chapter combustion processes are dealt with, and the speed of combustion, compression pressure, turbulence, atomization, humidity and ionization are some of the factors the influence of which is examined.

Fuels, the influence of their various properties on thermal efficiency and knocking tendencies, detonating and non-detonating fuels, detonation suppressers and inducers, and

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the fractionation of gasolines for internal-combustion engines according to spontaneous-ignition temperatures are discussed.

Among the conclusions drawn is that large purchasers of fuel should include in their specifications a minimum spontaneous-combustion temperature. This clause, it is said, will prove more useful than all others combined.

Die Berechnung einer Viertakt-Dieselmaschine. By W. Haeder. Published by Richard Carl Schmidt & Co., Berlin, Germany; 376 pp.; illustrations. **[E-1]**

The present volume, Design of a Four-Stroke-Cycle Diesel Engine, is a third Haeder handbook, similar in method and scope to the two previous publications dealing with an automobile engine and a two-stroke-cycle Diesel, respectively. The book develops the complete design of a compressorless four-cylinder four-stroke-cycle stationary Diesel engine having an output of about 225 hp. at a speed of 900 r.p.m.

While the material presented is concentrated on one particular engine and the figures used in the calculations are appropriate for it, the methods used are said to be applicable to all engines of this type. Clearness is aimed at in the style, and the most recent research results are said to have received consideration in the design rules laid down. About 30 working drawings are included as a supplement.

Automotive Methods and Practices Involved in Aircraft Engines. By O. E. Szekely. Paper presented at the semi-annual meeting of the American Society of Mechanical Engineers, Detroit, June 9 to 12, 1930. **[E-5]**

The author draws a striking comparison between the cost of standard parts in automobile manufacturing and the cost of parts in airplane manufacturing. Iron, steel and other metals that enter into automobile construction can be secured at apparently a much lower price than when it is known they are intended for use in airplanes. Although airplane making is a new industry, most of the principles involved in aircraft-engine manufacturing have long been practiced in the internal-combustion engine industry.

HIGHWAYS

Experience of a Public Transportation Company in the Prevention of Street and Highway Accidents. By L. G. Tighe. Paper presented at the National Safety Congress, Pittsburgh, Sept. 29 to Oct. 3, 1930. **[F-4]**

Accidents are seemingly fundamental to the transportation business, therefore transportation companies deem it necessary to maintain claim departments in addition to a well-trained personnel devoting all its efforts to claims and prevention of accidents. In such a department, records and statistics should be accurate, if they are to be useful to the management.

Mr. Tighe speaks about the functioning of such a department in the Northern Ohio Power & Light Co., of Akron, Ohio, of which he is assistant general manager. He firmly believes in well-organized accident prevention work that functions every day of the year.

Another paper presented at the Congress that may be of interest to the transportation engineer is entitled, How to Operate a Public Vehicle Safely, by Chester K. Thomas.

MATERIAL

The Influence of Engine Conditions on the Antiknock Rating of Motor Fuels. By R. Stansfield and F. B. Thole. Published in *Engineering*, Oct. 10, 1930, p. 468. **[G-1]**

The authors refer to the work of Earl Bartholomew, of the Ethyl Gasoline Corp., who arranged a series of detonation tests with cylinder-jacket temperatures varying

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from 212 to 400 deg. fahr. Blends of benzol and aviation gasoline were compared with aviation gasoline doped with ethyl fluid, and it was shown that considerably less ethyl fluid was needed to make a blend to match a given benzol blend at high jacket-temperatures than at low temperatures. Messrs. Stansfield and Thole point out, however, that the tests did not indicate the converse effect; namely, the amount of extra benzol required to make up the apparent loss of antiknock value at the higher temperatures. In view of the fundamental difference in behavior of the two materials, they decided to repeat the Bartholomew tests to obtain additional information.

They also desired to determine whether there were appreciable differences in rating when other fuels, including liquid-phase and vapor-phase cracked gasolines, alcohol blends, aviation gasoline and certain pure hydrocarbons, were used. Further, the examination of *n*-heptane blends with pure benzene was necessary in view of the frequent use of these substances as reference standards for antiknock rating.

In addition to a study of jacket-temperature effects over a wide range, tests were made to determine the influence of different degrees of inlet-air heating; of variation in throttle opening; of variation in the spark-plug gap and reach; and of alteration of ignition advance. The effect of such changes of humidity as are likely to be met in practice was also investigated.

The tests were made on the Armstrong Whitworth test engine fitted with a bouncing-pin indicator and a special instrument for rapidly determining the correct fuel feed.

The article is continued in the Oct. 24 issue of *Engineering*.

The Front-End Volatility of Motor Fuels Since 1927. By G. G. Oberfell and R. C. Alden. Published in *National Petroleum News*, Aug. 27, 1930, p. 59. [G-1]

Data for this paper were obtained from surveys of the Bureau of Mines and the Philips Petroleum Co. It was found that there is seasonal variation in front-end volatilities and that there has been a slow but steady increase in the front-end volatility of motor gasolines.

According to the authors, front-end volatility is determined by several factors; for example, the use of natural gas, cracking processes and the vapor systems at refineries.

The present rate of production of natural gasoline is more than 6,000,000 gal. per day, about 12 per cent of the motor fuel of the Country.

The use of vapor-recovery systems is increasing, and such equipment, besides conserving the material otherwise lost, have an advantage in controlling the front-end volatility of finished motor fuels.

The Phillips Petroleum Co. survey revealed that virtually all marketers control the front-end volatility over a considerable range, from 15 to 50 deg. fahr. at the 10-per cent-evaporated temperature. One marketer will maintain his summer product at 165 deg. fahr. while another will maintain it at 145 deg. fahr. at 10-per cent evaporated.

The success of the more volatile fuels is due to competitive and economic conditions within the industry.

Since specifications for gasoline sold within the boundaries of the several States are generally based upon the specifications of the Federal Specifications Board, volatile fuels, which from all evidences are gaining in favor, should be given more weight in considering a revision of specifications than the less volatile fuels of the past, the authors contend.

Automobile Steels. By Albert Muller-Hauff and Karl Stein. Translated by Hans Goldschmidt. Published by John Wiley & Sons, Inc., New York City, 1930; 219 pp., Price, $3.50. [G-1]

The designer, automobile plant manager, steel plant manager, business man and the man at the lathe will find the

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data assembled in this book of interest especially with regard to foreign and domestic practice. The original German text has been amplified by the addition of American Standards—a revamp from the S.A.E. HANDBOOK—and tables giving the steel specifications of foreign and domestic automobile manufacturers.

Aluminum-Silicon-Magnesium Casting Alloys. By R. S. Archer and L. W. Kempf. Paper presented at the meeting of the The American Institute of Mining and Metallurgical Engineers, Chicago, September, 1930. **[G-1]**

An investigation was made to find alloys suitable for the production of heat-treated castings capable of withstanding severe service. The machinability of aluminum-copper alloy was found to be somewhat better than that of the aluminum-silicon-mangensium alloys, although the latter can be commercially machined with standard tool set-ups, and, with adaptation of tools and machining methods to suit the material, can perhaps be machined as well as the aluminum-copper alloy.

Perhaps the chief advantage of the aluminum-silicon-mangnesium alloys lies in superior foundry characteristics, including ease of casting and relative insensitivity to high pouring-temperature. Corrosion resistance is higher than that of the 4-per cent copper alloy, especially when the iron content is kept low and no precipitation heat-treatment is used. Specific gravity and thermal expansivity are high in the aluminum-silicon-magnesium alloys, and, although reduced somewhat by the small additions of copper, are probably still higher than in most commercial aluminum alloys.

Modulus of Elasticity of Aluminum Alloys. By R. L. Templin and D. A. Paul. Paper presented at the meeting of the American Institute of Mining and Metallurgical Engineers, Chicago, September, 1930. **[G-1]**

The results presented in this paper are valuable because they furnish a general idea of the variation of the modulus of elasticity produced by the addition of the more common alloying elements to aluminum.

Thermal Conductivity of Copper Alloys. II—Copper-Tin Alloys. III—Copper-Phosphorus Alloys. By Cyril Stanley Smith. Paper presented at the meeting of the American Institute of Mining and Metallurgical Engineers, Chicago, September, 1930. **[G-1]**

This paper is a continuation of the work on the thermal conductivity of copper alloys described in the authors' previous paper. The thermal conductivity of copper is rapidly reduced by the addition of tin. Phosphorus is ten times as powerful as tin in reducing conductivity. The electrical conductivity decreases more rapidly on alloying than does the thermal conductivity, and the Wiedemann-Franz-Lorenz ratio increases rapidly at first but, beyond 2.0 per cent tin or 0.15 per cent phosphorus, remains almost constant. This break in the Wiedemann-Franz-Lorenz ratio curve has occurred in every system yet examined and is evidently of basic physical significance.

Constituents of Aluminum-Iron-Silicon Alloys. By William L. Fink and Kent R. Van Horn. **[G-1]**

Studies upon the Widmanstätten Structure, I—Introduction. The Aluminum-Silver System and the Copper-Silicon System. By Robert F. Mehl and Charles S. Barrett. **[G-1]**

Equilibrium Relations in Aluminum-Antimony Alloys of High Purity. By E. H. Dix, Jr., F. Keller and L. A. Willey. **[G-1]**

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Cemented Tungsten Carbide—A Study of the Action of the Cementing Material. By L. L. Wyman and F. C. Kelley. [G-1]

Application of X-Rays to Development Problems Connected with the Manufacture of Telephone Apparatus. By M. Baeyertz. [G-1]

Equilibrium Relations in Aluminum-Magnesium Silicide Alloys of High Purity. By E. H. Dix, Jr., F. Keller and L. A. Willey. [G-1]

Effect of Certain Alloying Elements on Structure and Hardness of Aluminum Bronze. By Selma F. Hermann and Frank T. Sisco. [G-1]

The preceding seven papers were also presented at a meeting of the American Institute of Mining and Metallurgical Engineers, Chicago, September, 1930.

Corrosion and Heat-Resistant Nickel-Copper-Chromium Cast Iron. By J. S. Vanick and P. D. Merica. Paper presented at the 12th annual convention of the American Society for Steel Treating, Chicago, Sept. 22 to 26, 1930. [G-1]

Laboratory, foundry and field investigations of three or four years' duration give in some detail the various characteristics of these cast irons through a wide range of chemical composition. The checks on the test results confirm a greatly increased service life for this material compared with plain iron, and a life comparable in many cases with bronze. It is a material that can be produced in any well-organized iron foundry and at a reasonably low cost.

Study of High-Chromium Low-Carbon Steel. By Arthur Phillips and Ralph W. Baker. Paper presented at the 12th annual convention of the American Society for Steel Treating, Chicago, Sept. 22 to 26, 1930. [G-1]

The first section of this paper records a series of experiments showing in a semi-quantitative way the rate of grain growth in a heat-resisting steel of 28 per cent chromium and 0.25 per cent carbon. Accompanying charts graphically correlate factors of time and temperature with grain size. The experimental evidence leads to the conclusion that in this steel the grains reach their maximum size after comparatively short periods at high temperatures.

The second part of the paper is confined to the study of the micro-structure of steel containing approximately 28 per cent chromium and carbon contents ranging from 0.07 to 0.26 per cent. With reference to the structural changes and the effect of carbon on the alpha-gamma and gamma-delta points, previous investigations have placed the maximum carbon content for gamma-free alloys at about 0.02 per cent. The experimental results discussed in this paper place the limit at approximately 0.10 per cent carbon.

Further Research on Helical Springs of Round and Square Wire. By A. M. Wahl. Paper presented at the semi-annual meeting of the American Society of Mechanical Engineers, Detroit, June 9 to 12, 1930. [G-1]

A method of calculating the stress in helical springs of square wire is proposed. The method is to use an approximate formula, based on St. Venant's results for torsion of rectangular wire, and multiply by a correction factor based on the spring index. The method is quantitatively checked by strain measurements both on semi-coil and actual square-wire springs and on complete springs loaded in compression. It is suggested that this new formula replace those commonly given in handbooks, which may lead to considerable error in certain cases.

Deflection measurements between coils of helical round-wire tension springs made from the same bar but having

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spring indexes varying from 2.7 to 9.5 indicate that the ordinary helical-spring formula for round wire gives results quite close to the actual deflection.

A simple approximate formula, based on St. Venant's results, for deflection of rectangular-bar springs is proposed to replace those ordinarily used and commonly given in handbooks. These ordinary deflection formulas may also lead to considerable error in certain cases.

Flow Characteristics of Special Fe-Ni-Cr Alloys and Some Steels at Elevated Temperatures. H. J. French, William Kahlbaum and A. A. Peterson. Paper presented at the semi-annual meeting of the American Society of Mechanical Engineers, Detroit, June 9 to 12, 1930. [G-1]

In this paper the authors give the results of creep tests at different temperatures for three groups of alloys. A metallographic study of the creep-test specimens revealed intercrystalline weakness in some of the wrought nickel-chromium-iron alloys, especially at temperatures between 1160 and 1390 deg. fahr. A study was also made of the effect of deformation in the creep tests at different temperatures on the hardness and impact resistance of a chromium-vanadium steel at atmospheric temperatures.

Textbook of the Materials of Engineering—Fourth Edition. By Herbert F. Moore. Published by McGraw-Hill Co., Inc., New York City, 1930; 409 pp. Price, $4. [G-3]

Although elementary in character, this textbook is a concise presentation of the physical properties of the common materials used in structure and machines, with descriptions of their manufacture and fabrication. In this new edition the material is brought up to date, some chapters have been rewritten and several new chapters added. A chapter on the crystalline structure of metals was written by Prof. J. O. Draffin, and one on concrete was written by H. F. Gonnerman.

MISCELLANEOUS

Steady Forced Vibration as Influenced by Damping. By Lydik S. Jacobsen. Paper presented at the semi-annual meeting of the American Society of Mechanical Engineers, Detroit, June 9 to 12, 1930. [H-1]

The author presents a general method of obtaining approximate solutions of the steady forced vibration of a damped system of one degree of freedom for the case of sinusoidally varying disturbing forces. The approximation consists in expressing all the damping terms of the original differential equation by a single equivalent damping term, proportional to the first power of the velocity of motion.

In the case of a system influenced by a centrifugal disturbing force and damped by constant friction and by friction proportional to the first power of the velocity, experimental evidence is in good agreement with the approximate solution.

Thermometric Lag of Aircraft Thermometers, Thermographs, and Barographs. By H. B. Hendrickson. Published in the *Bureau of Standards Journal of Research*, September, 1930, p. 695. [H-1]

A constant, which will be called the time lag, has been determined experimentally for thermographs, barographs and for the temperature element of a Fergusson meteorograph. When the instruments are exposed in the same medium and to the same ventilation, this constant can be used to evaluate their thermometric lag. For the purpose of comparison, this constant was also measured for a number of laboratory thermometers. Tests on the thermometers and thermographs were made in an airstream of 17 m.p.h.

Results for the thermometers show that the liquid-filled

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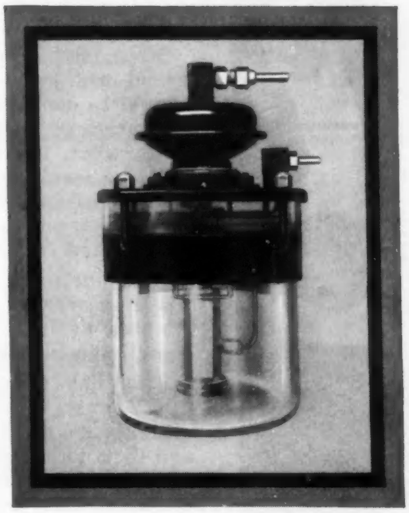

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type has the greatest time lag and therefore, under similar conditions of exposure, the greatest thermometric lag, followed in order by the bimetallic strip type and the electrical-resistance thermometers. All of the barographs, even the metal-cased types, have a far greater time lag than the thermometers, but the lag is reduced considerably by moderate ventilation. The lag of the thermometers ranged from 3 to 72 sec., whereas that of the barographs in still air ranged from 22 to 64 min. The lag of the temperature element of the meteorograph was found to be 3 min. in still air and 11 sec. in an airstream of 17 m.p.h.

Les Calibres Vérificateurs des Filetages. By L. Fraichet. Published in *La Technique Moderne*, Oct. 15, 1930, p. 689. **[H-1]**

The methods at present in use by a great number of French firms for checking the threads of screws and bolts are not sufficiently reliable, in the opinion of the author, who is associated with the aeronautical technical service of France, and whose article on this subject refers primarily to practices in the aircraft industry.

First, the principles on which the inspection should be based are enunciated. These, according to the author, should be such as to secure both interchangeability and the limitation of variations within reasonable values. He sets forth what, in his opinion, are correct inspection methods and the conditions that should be observed in the manufacture of gages. As a specific example, he details the methods used for spark-plugs, contrasting those used in France and in Germany, to the advantage of the latter.

The Engineer's Vest-Pocket Book. By W. A. Thomas. Published by the W. A. Thomas Co., Chicago, 1930; 151 pp. and classified directory. Price, $3. **[H-3]**

This handy reference book is unusually replete with tables, curves, formulas, illustrations and examples. The contents are divided into 12 sections: mathematics, statistics and dynamics, strength of materials, building construction, mechanical design, heat, hydraulics, chemistry and physics, electrics, transportation, surveying and general.

The classified directory of companies listed by products or services should prove most useful to engineers in the various fields.

Die Design and Diemaking Practice. Edited by Franklin D. Jones. Published by The Industrial Press, New York City, 1930; 921 pp., 590 illustrations. Price, $6. **[H-3]**

For many years the publishers of *Machinery* have been receiving drawings and descriptions of all kinds of standard and special dies from die specialists in every branch of sheet-metal manufacture. This storehouse of costly die experience, methods and principles is presented clearly and concisely in the present volume. Dies for every conceivable purpose are described and shown by drawings, so that the information given is capable of general application.

MOTORCOACH

A Study of 1929 Motor-Bus Operating Costs. Published by the National Association of Motor-Bus Operators, City of Washington, 1930. **[J-4]**

In compiling this statistical study of motorcoach operating costs, an attempt was made to find those variable factors common to all operations on which costs most greatly depend. Since there was a correlation between seating capacity and number of vehicles in the fleet, the average seating capacity of the fleet is used as a basis of correlation.

Incongruities in simple curves were due to lack of suffi-

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cient sample at certain points; therefore a system of moving weighted averages was adopted.

Items such as gasoline consumption and coach mileage were also subjected to cross-checking. Moving averages for miles per gallon, gallon per vehicle, and cost per gallon, and for miles per coach, costs per coach-mile and revenues per coach-mile were struck, and the various curves thus revealed were required to tally with the direct curve sought

MOTOR-TRUCK

Motor-Truck Impact as Affected by Rubber Tread Thickness of Tires. Reported by James A. Buchanan. Published in *Public Roads*, September, 1930, p. 133. [K-1]

The experimental motor-truck impact tests reported in part in the June, 1926, issue of *Public Roads* have been continued and the scheduled tests on cushion and solid tires cut to various heights of tread rubber have been completed.

The object of this particular phase of the impact investigations was to determine the effect of reducing the thickness of the tread rubber on the cushioning properties of typical solid and cushion tires.

Since the tests reported in this article were conducted, a thorough investigation of the accuracy of the instruments used has been made by the United States Bureau of Standards, in cooperation with the United States Bureau of Public Roads. A summary account of this work was published in *Public Roads*, July, 1930, and reviewed in this column of the November issue of the S.A.E. JOURNAL.

This is a cooperative investigation that is being conducted by the Bureau of Public Roads with the cooperation of the Rubber Association of America and the Society of Automotive Engineers.

Der Vorderradantrieb für Nutzfahrzeuge. By Dr. Manlik. Published in *Automobiltechnische Zeitschrift*, Aug. 20, 1930, p. 552. [K-1]

After briefly summarizing the distinctions between front and rear-wheel drives, the author selects, as the feature of most significance for commercial vehicles, the difference in traction obtainable. While the front-wheel drive is said to be at a disadvantage in this respect in level steady running, it is even further handicapped in hill-climbing and acceleration. In a mathematical exposition of this point, the author compares front and rear-wheel drives and concludes that the utility of the former type of transmission for commercial vehicles is very doubtful.

PASSENGER CAR

Olympia Show, 1930-1931. Published in *The Autocar*, Oct. 17, 1930, p. 731. [L-1]

The 24th annual international automobile exhibition held in London, England, had two additional sections, this year, one for the special display of marine engines and equipment and another for improved garage equipment. The keynote of the show was "better cars and better values."

Although the number of exhibitors (592) was greater than in previous years, the number of car exhibitors was smaller. The 79 makers of cars are responsible for 205 different engines. The change from six to eight cylinders was decidedly noticeable. This was due to certain American firms having abandoned the six in favor of the eight and the fact that most of the absentees were in the six-cylinder category. Only three new four-cylinder cars have been introduced.

Another noticeable feature was the lowering of the chassis and the simplification of its lubrication.

The tendency in transmissions is toward simplicity and silence, many firms having adopted free-wheeling, which makes gear-changing easy.

Among the novel cars the Daimler was the most dis-

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tinctive and original. It has unusual shock-absorbers for the front axle, articulated rear axle, an aluminum eight-cylinder engine and tubular frame. Its most outstanding feature is its fluid flywheel, a radical invention that reduces the need of gear-changing to the absolute minimum and allows the car to glide away from rest on the level or uphill without use of the clutch.

The frame of the Lancia is highly unconventional. The front has no axle, as the term is usually understood, and coil springs replace the familiar leaf springs in front. The Steyr has independent suspension for each of its rear wheels.

All this goes to show, observes the writer, that the European industry is well to the forefront of ordinary design and that it is still possible for a firm to break away entirely from the accepted tenets of convention and yet be successful.

Burney Streamline Car. Published in *The Motor*, Sept. 16, 1930, p. 277. [L-1]

This definitely advanced vehicle of ultra-modern appearance is the embodiment of an ideal. Sir Dennistoun Burney, designer of the R-100 and inventor of note, has designed the most novel yet practical car produced in years. With the engine in the rear, there is no noise, smell or heat in the body. The body is fully streamlined and even the head-lamps do not project.

The main features of the car are that the body and chassis frames form one unit-girder structure. All four wheels are independently sprung, each of the front wheels being steered by a separate drag-link. The engine is just behind the rear axle, and the transmission, which has drive direct on third speed and has a silent top speed, is just in front of the axle. The car is driven by a straight-eight Beverly Barnes engine, and has a Bishop steering-gear and Lockheed hydraulic brakes. The gear change is unusual in that first-speed gear and the over-geared top-speed gear are on one side of the gate, second and third being on the other side. Cooling of the engine is effected by two large radiators mounted vertically on either side of the forward end of the engine on silent-bloc trunnions. The air is directed to them by large scoops in the tail of the body and emerges through numerous louvers, while a belt-driven fan with adjustable mounting is placed in front of each radiator.

Another noteworthy feature is the suspension, which is effected at the rear by short transverse cantilever springs, so placed that they are side by side for about half of their length. The trunnions of each spring are mounted on the frame members. No shock-absorbers are needed at the rear.

The controls have been very well thought out and, as in aircraft practice, consist of flexible cables running through copper tubes.

This seven-passenger salon model has proved itself in road tests and all-round performance. It is selling for £1,500.

Le XXIVe Salon de l'Automobile et du Cycle. By G. Delanghe. Published in *Le Génie Civil*, Oct. 18, 1930, p. 377. [L-1]

Regret is expressed, in this review of the 24th Paris automobile salon, that no formal exhibition of commercial vehicles is to be made this year. It was omitted since it would, if held, have unduly delayed the aircraft show.

Of the 1200 exhibits, the greater part were of French origin, with the United States second in the importance of its representation. France's automotive industry now ranks third among the nation's industries, employing 420,000 workers, using 300,000 tons of metal per year and producing last year about 250,000 vehicles. Last year set a record in the rate of increase in passenger-car usage.

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Notes and Reviews

Concluded

putting France in the third place among the nations in the number of automobiles in proportion to population. In production she ranked second.

A reduction in the number of new models characterized this year's show, as it did last year's, and while novel or radical developments are conspicuously absent, a sharp reaction in favor of the small 5 and 6-hp. cars is noted.

The eight-cylinder engine is pushing the six hard in the high-priced field, the six having, in the opinion of the author, passed the apogee of its favor. The four-cylinder engine still holds its own as the utilitarian power-plant. The increase in engine speeds has been checked, production models, as a rule, not exceeding 3000 r.p.m.

Magneto manufacturers are fighting the American ignition invasion with the latter's own weapons, turning to the manufacture of storage batteries. Oil coolers and filters are becoming more common. Downdraft carbureters are attracting much attention, as are also accelerating pumps and carbureters having two jets in addition to the idling jet, one of which is brought into play when the engine is called on to deliver maximum power.

Four-speed transmissions and three-speed transmissions with auxiliary speeds are increasing in use, and centralized lubrication is taken as a matter of course on high-priced cars. Flexible bodies have virtually disappeared.

In addition to the general technical comments, the article contains descriptions of the more important exhibits.

Know the Ford—First Edition. By Murray Fahnstock. Published by the Trade Press Publishing Co., Milwaukee, 1930. [L-2]

This book is unusual in that 21 chapters and more than 160 illustrations are devoted to explaining in an easily understood way the engineering and service features of the Model-A Ford car. Descriptions of the more easily made adjustments and repairs are included, but the book is not intended to be a complete service manual for the use of the mechanic.

The author explains why the Ford company features four cylinders and non-adjustable valves with mushroom stems, and the reasons for the use of transverse springs, the position of the gasoline tank, design of the steel-spoke wheel, the brakes, the use of such alloys as those containing chromium, manganese and nickel, and the reasons for the use of different kinds of ball and roller and graphite bearings in various parts of the car.

TRACTOR

The Krasny Putilovetz Tractor Works. Published in *Automobile Engineer*, September, 1930, p. 314. [M-5]

The Krasny firm was founded in Russia in 1801 and was purchased in 1868 by N. I. Putilov, who reorganized it into a giant enterprise. Its activities included the manufacture of merchant ships, warships, locomotives and railroad cars. Most of these activities are still being carried on in the factory, but the latest development consists in utilizing a large portion of the old buildings, augmented by new wings, for the mass production of tractors. The equipment in the main is of uptodate character, most of it having been purchased from America.

Among the workers there is general enthusiasm. Technical literature is widely and generally studied, and they demand that the latest machine-tools be bought. As a result, the equipment, organization, floor space and so on are greatly in excess of that usual in other countries for a given output.

The author discusses the control of the factory, which rests in three distinct departments known as the Elective, the Administration, and the Works Committees. Wages, work week, housing, schools and conditions in general that affect the worker are given and described.

Personal Notes of the Members

(*Continued from p. 723*)

I. Enos Larkin, former sales engineer for the Link Belt Co., of Chicago, is now serving the Barber Greene Co., of Aurora, Ill., as salesman for portable machinery.

R. H. Manson, vice-president and chief engineer of the Stromberg Carlson Telephone Mfg. Co., of Rochester, N. Y., was recently nominated for the presidency of the Institute of Radio Engineers, an international body having members in this Country and abroad. Mr. Manson has been a member of the Society for the last 18 years.

Dr. Miller McClintock, director of the Albert Russell Erskine Bureau for Street Traffic Research of Harvard University, has been elected vice-president of the Institute of Traffic Engineers, a National organization founded in New York City in October. Headquarters of the Institute are to be located at 175 Fifth Avenue, New York City. The primary objects are to further the interests of the profession of traffic engineering, encourage and foster traffic-engineering education in colleges of engineering, and to establish a clearing house for authoritative pronouncement on matters relating to street travel.

As a result of the expansion of the United Aircraft & Transport Corp., **George J. Mead, vice-president of the** Pratt & Whitney Aircraft Co., in charge of engineering, has been made head of the newly organized experimental and research division of the United Aircraft & Transport Corp. and will also be chairman of the executive committee of the Pratt & Whitney Aircraft Co. **A. V. D. Willgoos**, chief engineer of the latter company, will be assisted by **L. S. Hobbs**, research engineer, and **T. E. Tillinghast**, executive engineer.

J. P. Miller, who lately assumed the duties of chief draftsman in the engine division of the Dee Wite Boat Co., of Detroit, is a former engine designer for the Studebaker Corp., of South Bend, Ind.

H. G. Osborn, a long-time Member of the Society, and engineer in the Osborn Engineering Laboratory, of Owosso, Mich., is now connected with the Essex Wire Corp., located in the west portion of the Ford plant at Highland Park, Mich.

Rafael J. Pagan, former manager of the Self Auto Corp., of San Juan, Porto Rico, is now president and general manager of the Puerto Rico Drivyurself & Garage Co., of San Juan, Porto Rico.

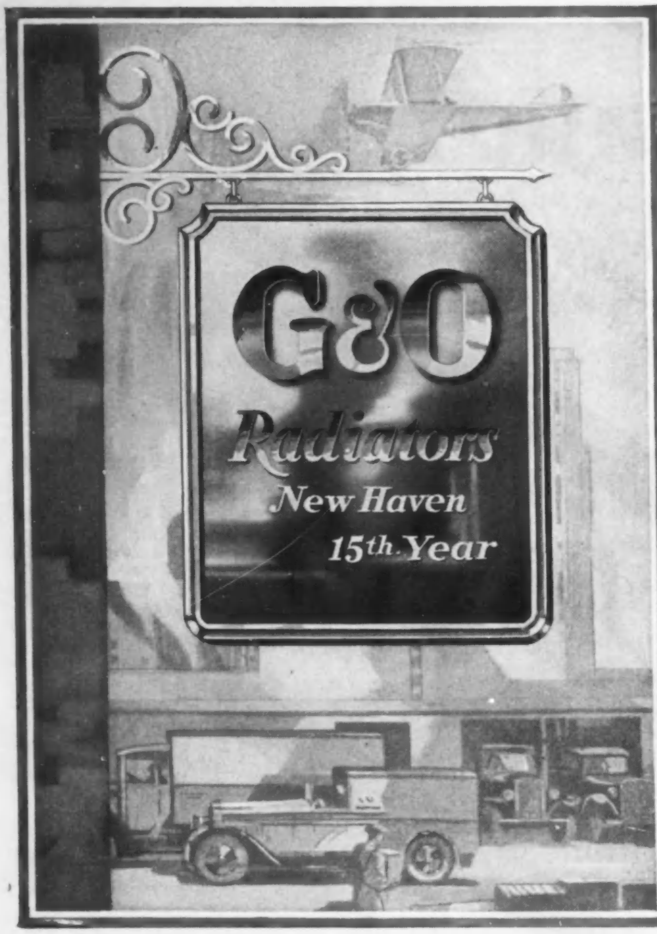
Earl Riebe Pierce, a former student at the Sheffield Scientific School, Yale University, is now employed in the General Motors Research Laboratory at Detroit as a junior engineer.

William Hudson Ragsdale is now serving the Davis Devices Co., of Clarksburg, W. Va., in the capacity of experimental engineer, having relinquished a similar position with the Lycoming Mfg. Co., of Williamsport, Pa.

Beppe Romersi, an Italian engineer, who recently relinquished his post as engineer of S. A. Officine di Villar Perosa, at Turin, Italy, has come to this Country to study the organization of manufacturing plants. He is at present at the Morse Chain Works, at Ithaca, N. Y.

Edward A. Ruiz, who has been in charge of export billing and consular service for the Brockway Motor Truck Corp., in New York City, has severed his connection with that company to become export manager for the Otis Engine Corp., of Brooklyn, N. Y.

(*Concluded on next left-hand page*)



Personal Notes of the Members

Concluded

George H. Townsend has been elected president of the newly-formed Hurley-Townsend Corp., of New York City.

E. S. Wallace, who is serving the Chevrolet Motor Co., has been transferred from the Detroit plant, where he was acting as mechanical engineer, and has been made plant manager for the company at Bay City, Mich.

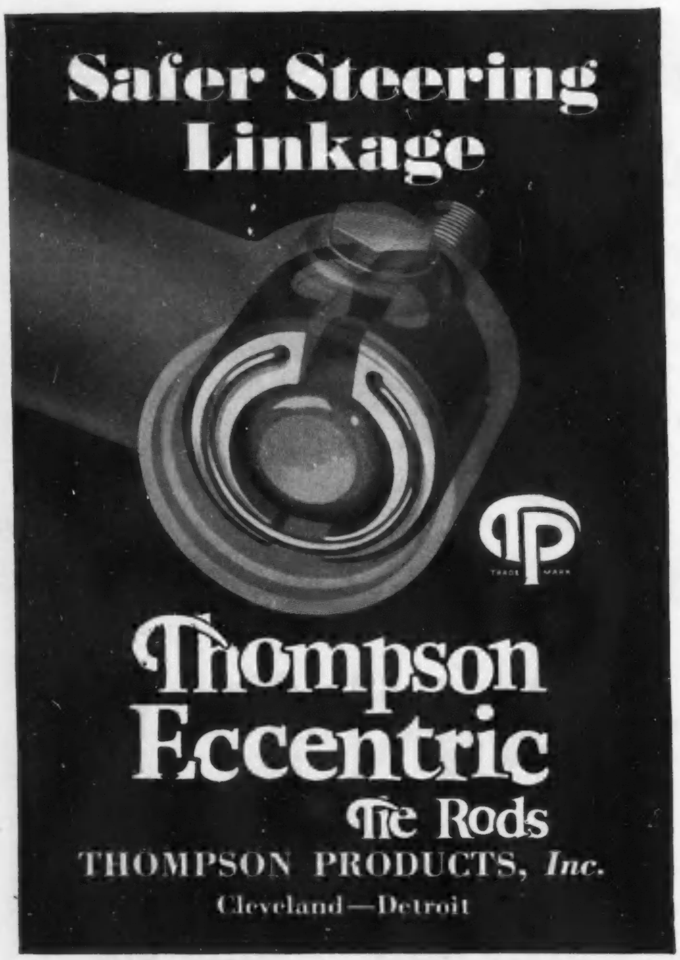
I. Piao Wang, a former student at the Massachusetts Institute of Technology, has entered Cornell University, at Ithaca, N. Y.

Ernest O. Wheeler is now service manager for the Ridlon Truck Sales, Inc., of Brighton, Mass. He was formerly transportation manager and maintenance engineer for the Pilgrim Laundry Co., of Boston.

George L. Williams, a former student of the Massachusetts Institute of Technology, has been made a research assistant in aeronautical engineering at that institution.

Having relinquished his position as designer with the International Motor Co., of Long Island City, N. Y., **Raymond C. Wilson** is now an engineer with the Chain Saw Corp., also of Long Island City.

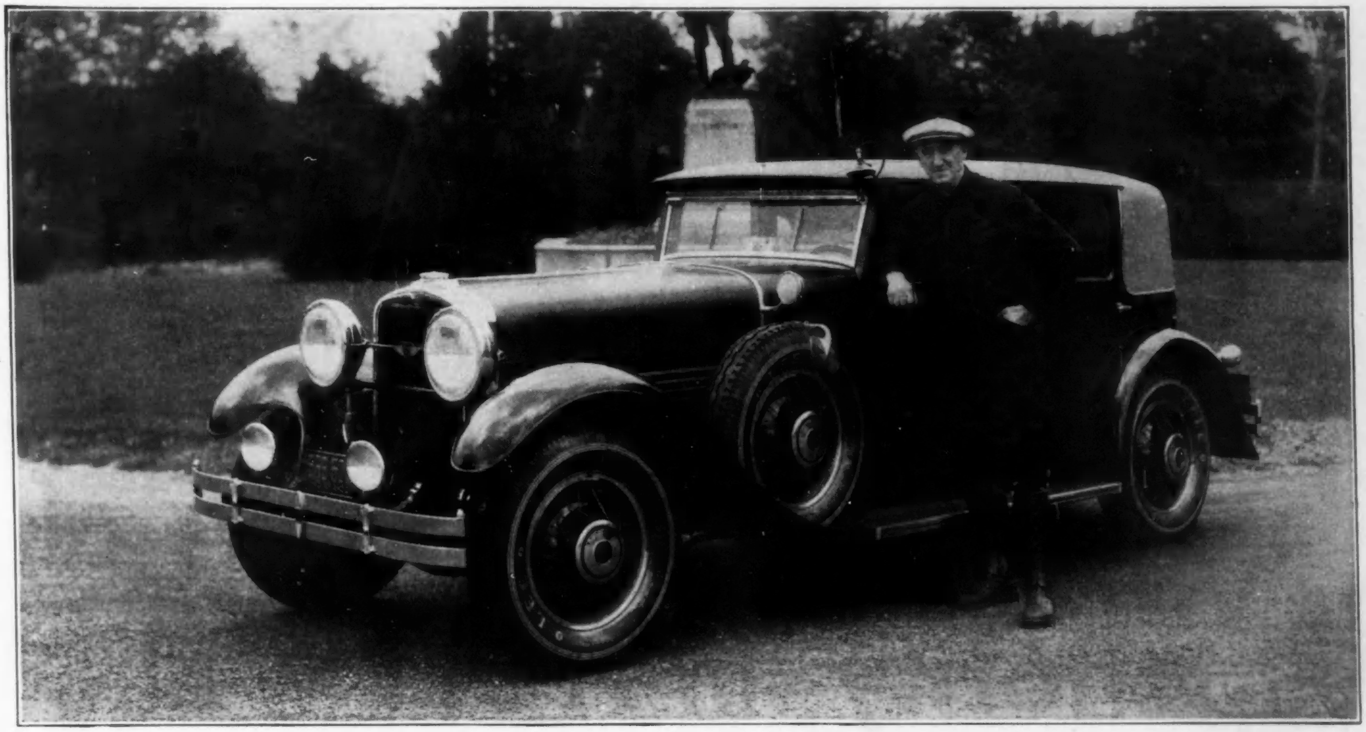
Albert H. Wood has been transferred from the General Motors Corp. factory at Oshawa, Canada, as technical manager of the Olds and Viking Division, to General Motors Products of Canada, Ltd., at London, Ontario, and has been put in charge of all General Motors products.



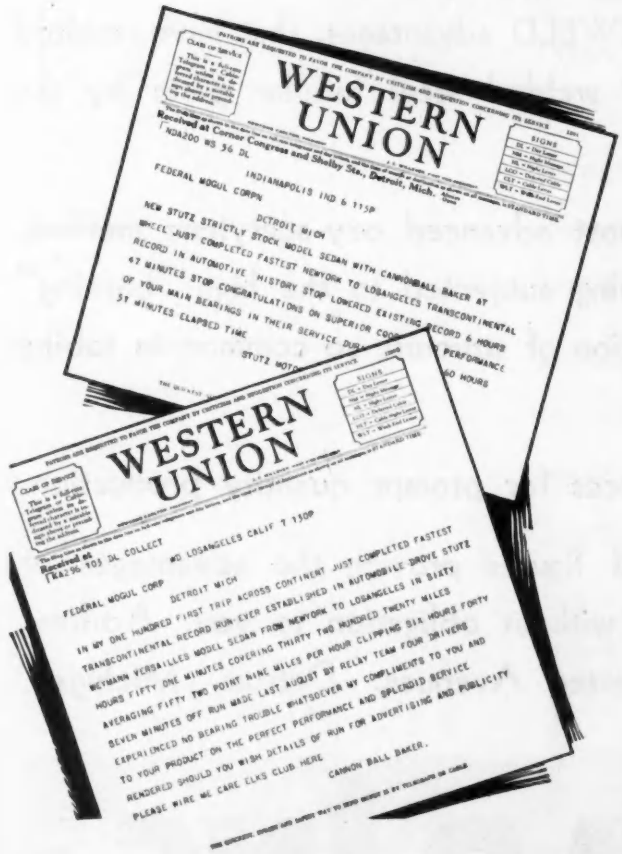
Last Call for Information for the S.A.E. Roster for 1931

If you want to be listed correctly in the 1931 S.A.E. Roster be sure and fill out the Roster blank which was recently sent to you and then mail it in right away.

Society of Automotive Engineers, Inc.
29 West 39th St.
NEW YORK, N. Y.



Cannon Ball Baker Sets Astonishing New Transcontinental Record With Federal-Mogul Equipped, Stock Model Stutz!



WESTERN UNION

Received at Corner Congress and Shelby Sts., Detroit, Mich.

NDA200 WS 56 DL

INDIANAPOLIS IND 6 115P

FEDERAL MOGUL CORPN

DETROIT MICH

NEW STUTZ STRICTLY STOCK MODEL SEDAN WITH CANNONBALL BAKER AT WHEEL JUST COMPLETED FASTEST NEWYORK TO LOSANGELES TRANSCONTINENTAL RECORD IN AUTOMOTIVE HISTORY STOP LOWERED EXISTING RECORD 6 HOURS 47 MINUTES STOP CONGRATULATIONS ON SUPERIOR CO[illegible] PERFORMANCE OF YOUR MAIN BEARINGS IN THEIR SERVICE DUR[illegible] 60 HOURS 51 MINUTES ELAPSED TIME

STUTZ MOTO[illegible]

WESTERN UNION

Received at

TKA296 103 DL COLLECT

WO LOSANGELES CALIF 7 130P

FEDERAL MOGUL CORP

DETROIT MICH

IN MY ONE HUNDRED FIRST TRIP ACROSS CONTINENT JUST COMPLETED FASTEST TRANSCONTINENTAL RECORD RUN EVER ESTABLISHED IN AUTOMOBILE DROVE STUTZ WEYMANN VERSAILLES MODEL SEDAN FROM NEWYORK TO LOSANGELES IN SIXTY HOURS FIFTY ONE MINUTES COVERING THIRTY TWO HUNDRED TWENTY MILES AVERAGING FIFTY TWO POINT NINE MILES PER HOUR CLIPPING SIX HOURS FORTY SEVEN MINUTES OFF RUN MADE LAST AUGUST BY RELAY TEAM FOUR DRIVERS EXPERIENCED NO BEARING TROUBLE WHATSOEVER MY COMPLIMENTS TO YOU AND TO YOUR PRODUCT ON THE PERFECT PERFORMANCE AND SPLENDID SERVICE RENDERED SHOULD YOU WISH DETAILS OF RUN FOR ADVERTISING AND PUBLICITY PLEASE WIRE ME CARE ELKS CLUB HERE

CANNON BALL BAKER.

Through fog and frost, chuck holes and ruts, through Stygian darkness and burning sunshine, Cannon Ball Baker drove from New York to Los Angeles in 60 hours, 51 minutes, clipping 6 hours, 47 minutes off the previous record. His car, a stock model Stutz, was equipped with Federal-Mogul bearings, and its connecting rods babbitted with genuine Federal-Mogul babbitt.

That Federal-Mogul has aided in building such stamina and ability to "stand the gaff" into the new Stutz is an outstanding example of Federal-Mogul dependability, of which we are justly proud.

We congratulate Mr. Baker and the Stutz Motor Car Company alike for this remarkable achievement.

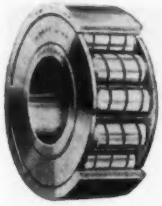
The Complete Federal-Mogul Line

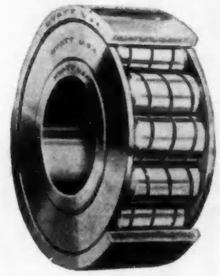
Mogul FEDERAL

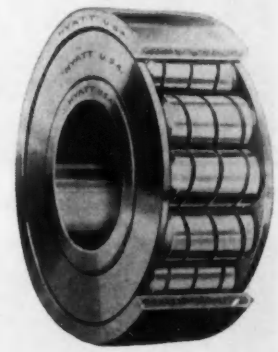
- Bronze-Back, Babbitt-Lined Bearings
- Steel-Back, Babbitt-Lined Bearings
- Die-Cast Babbitt Bearings and Bushings
- Bronze Bushings and Bronze Washers
- Bronze Castings
- Bronze Cored and Solid Bars
- Babbitt Metals
- Die Castings

We will exhibit at the National Automobile Shows to be held at Grand Central Palace, New York, January 3rd to 10th, 1931; and at the Coliseum, Chicago, January 24th to 31st, 1931.

FEDERAL-MOGUL CORPORATION - DETROIT, MICHIGAN

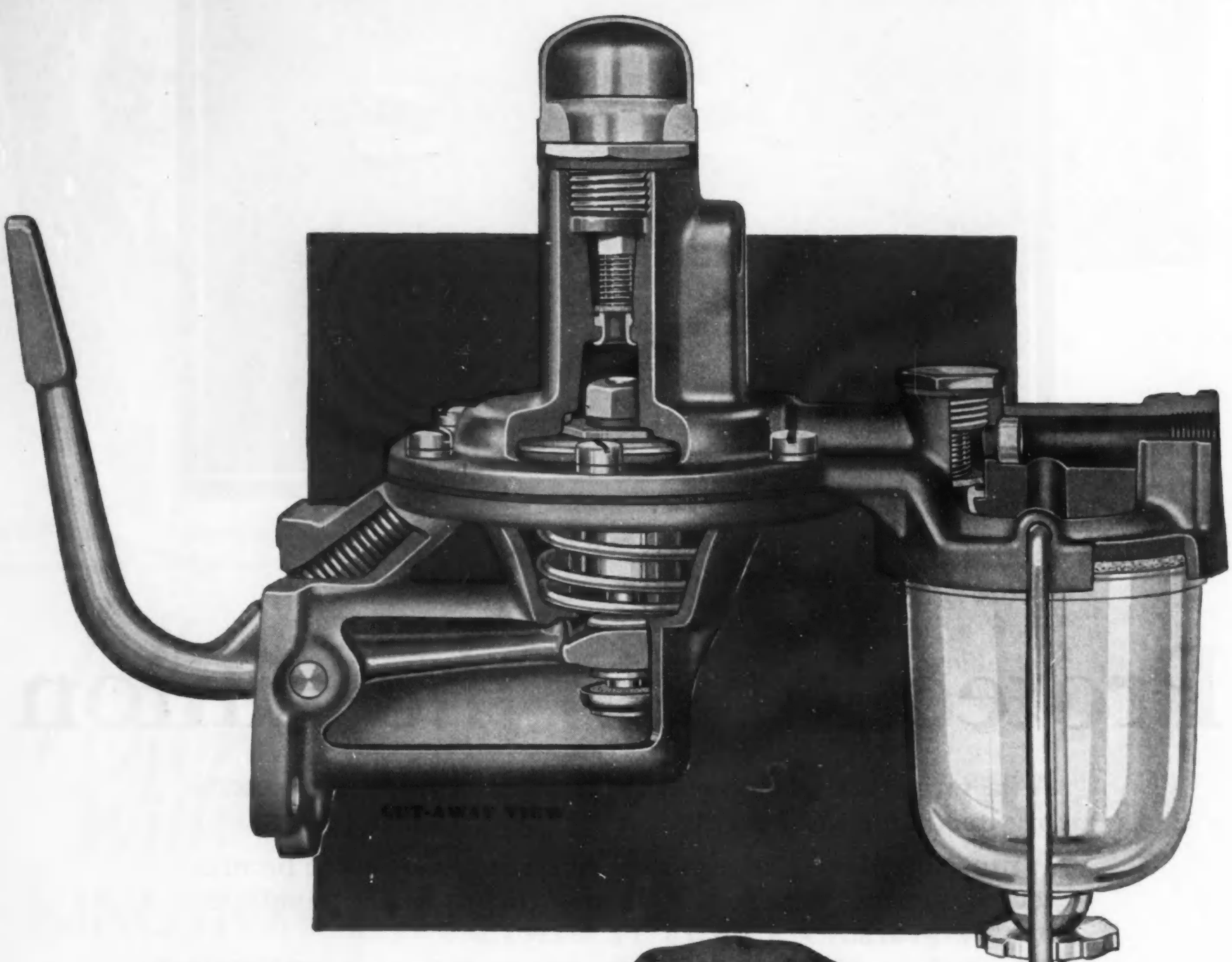


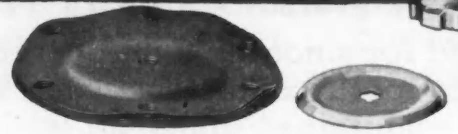




S. A. E. JOURNAL, December, 1930; Vol. XXVII, No. 6. Published monthly by the Society of Automotive Engineers, Inc., 29 West 39th Street, New York, N. Y. $1 per number, $10 per year; foreign, $12 per year; to members 50 cents per number, $5 per year. Entered as second-class matter, Jan. 14, 1928, at the post office at New York, N. Y., under the Act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized on Jan. 14, 1928.

The FUEL PUMP *with*





DIAPHRAGM PLATE

Note These Five Big Features of the Stewart-Warner Pump

1 Compensating Diaphragm reduces priming time.

2 Vapor Dome—promotes uniformity of discharge pressure.

3 Constant Fuel Rise—prevents segregated vapor traps.

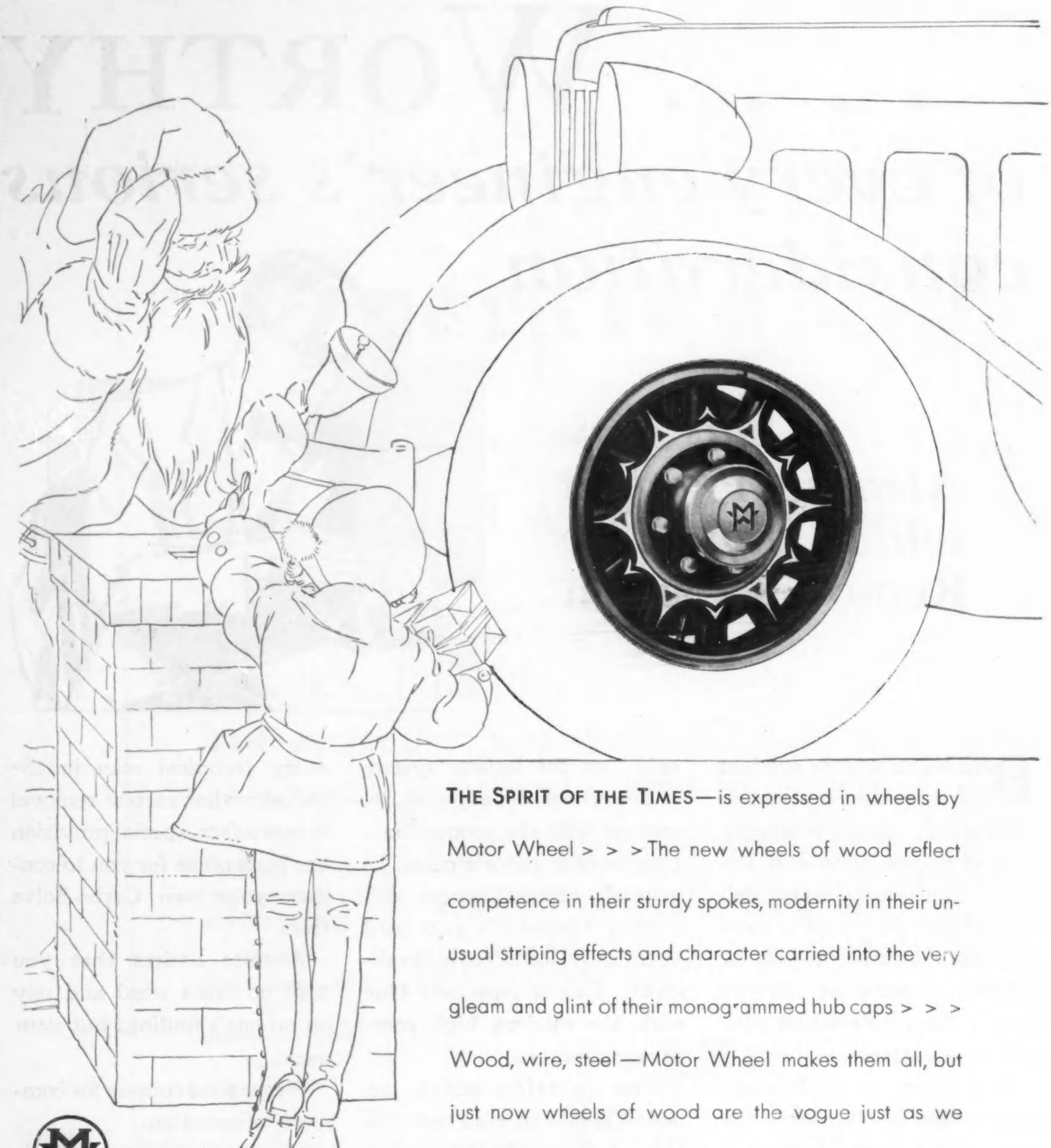
4 One-piece Cam Lever—one pivot only—no linkage.

5 Self-draining pocket for follower spring.

Note the even surface of the diaphragm, also its freedom from wrinkles in the flexing margin. (Edge is turned up to show laminations.) The plate has a specific shape designed to compensate for the "bag effect" of the diaphragm and also to prevent wear. The size and form of this plate working against the diaphragm brings about a material reduction in priming time.

STEWART

» » » » *TRAFFIC TESTED*



A pneumatic grinder, die-cast from an alloy of Horse Head Zinc.

RELAY TRUCKS DEPEND on LONG RADIATORS for Efficient Engine Cooling

LONG PRODUCTS

AUTOMOTIVE CLUTCHES and RADIATORS

LONG

LONG MANUFACTURING COMPANY

Division of Borg-Warner Corporation

DETROIT, MICHIGAN


HERCULES ENGINES
HEAVY-DUTY POWER FOR EVERY ROAD BUILDING REQUIREMENT
HERCULES ENGINES
SEE THEM AT THE ROAD SHOW
ST. LOUIS-JANUARY 10-16
HERCULES MOTORS CORPORATION, CANTON, OHIO, U.S.A.


PINES
WINTERFRONT
—It's Automatic
IT IS A MATTER OF RECORD IN THE HISTORY OF AUTOMATIC MOTOR PROTECTION SUPPLIED AS STANDARD EQUIPMENT THAT THE PUBLIC WILL NOT ACCEPT A SUBSTITUTE.
THE MOTOR CAR OWNER WILL CONTINUE TO LOOK FOR THE BUILT-IN PINES AUTOMATIC WINTERFRONT BECAUSE MILLIONS HAVE LEARNED THAT A CAR WILL NOT OPERATE EFFICIENTLY WITHOUT ONE.
THE PUBLIC REALIZES THE IMPORTANCE OF THE PROTECTION PROVIDED BY THE PINES WINTER-FRONT AND WILL CONTINUE TO INSIST UPON IT IN THE CARS THEY BUY.
PINES WINTERFRONT COMPANY
1129 North Cicero Avenue
CHICAGO
Detroit Office:
2209-10 Fisher Building

INDEX TO ADVERTISERS' PRODUCTS

(Continued on page 82)

Manufacturers of Products Conforming to S.A.E. Specifications

Advertisers whose products conform to S.A.E. specifications are also listed in the S.A.E. Handbook List of Manufacturers, beginning on page 633, of the 1930 issue of the Handbook.

The addresses of companies listed in this index can be obtained from their current advertisements indexed on page 86.

INDEX TO ADVERTISERS' PRODUCTS

(Continued on page 84)

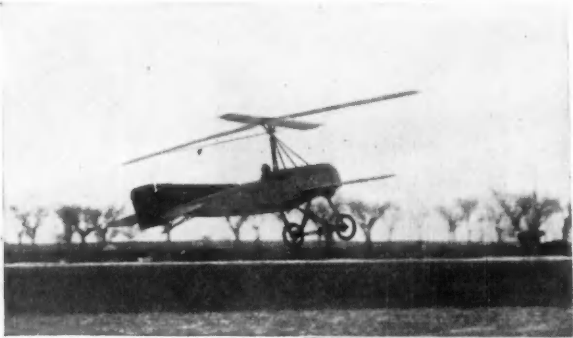
INDEX TO ADVERTISERS' PRODUCTS

INDEX TO ADVERTISERS

The Index to Advertisers' Products is given on pages 80, 82, and 84

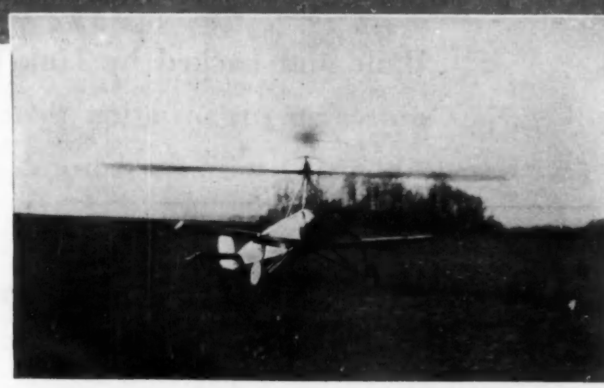
The Autogiro . . .

its ten years of development



Above: January 17, 1923. The Autogiro's first successful flight, at Madrid—an epoch-making triumph even though the ship covered but 200 yards.

Centre: Two ships of the latest type flying over New York Bay in November, 1930. Self-starting rotor blades permit 30-yard take-off.



Lower Right: December 19, 1928. First flight in America—a ship of proven practicability, but still compelled to taxi about the field to gather the needed speed for its rotor blades.

Many who saw the Autogiro for the first time at the National Air Races in Chicago, and many who have witnessed the numerous public demonstrations that have followed, believe it to be new and untried. It is neither.

Cierva's first theoretical conception of the idea of freely-rotating wings was in 1920, when he became convinced that safety in flight must in some manner be divorced from the necessity for continuous high speed. As a result of his intensive study and experiments with models, the first full-sized Autogiro was built in 1922 and was followed early in 1923 by the first machine to fly in full control of the pilot.

Since 1923 experimental work has been continued without interruption and during this period over seventy machines have been built and flown, each one incorporating some improvement or refinement of design over its predecessors.

A study of Cierva's "Theory of the Autogiro"—a complete engineering treatise on design—removes any element of mystery attached to the Autogiro's performance and shows it to be a unique but sound application of fundamental aerodynamic principles.

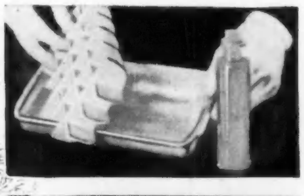
The Pitcairn-Cierva Autogiro Company is not a manufacturing but an engineering and licensing organization exclusively. It holds all rights under the Cierva patents for the United States. It will license qualified manufacturers to produce and sell Autogiros, and will extend to each licensee the full co-operation of its engineering and development resources.

And it is now prepared to acquaint the industry with Autogiro principle, design and construction—to arrange demonstrations and to discuss production privileges.

AUTOGIRO

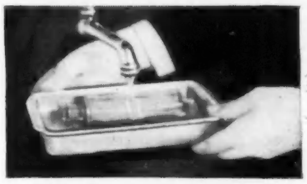
PITCAIRN-CIERVA AUTOGIRO COMPANY OF AMERICA

LAND TITLE BUILDING PHILADELPHIA, PA.

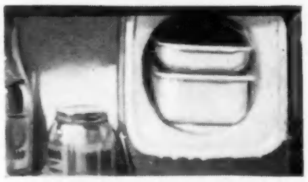


Remove the ice-cube separators from one of the freezing pans of your refrigerator.

2 Place a bottle of the new crack-proof Texaco Motor Oil, not quite full, in the pan.



3 Fill the pan with water so that the bottle of the new Texaco is completely immersed.



4 Replace in the freezing compartment of your refrigerator and leave it overnight.

5 In the morning, remove the cake of ice from the pan and watch the oil flow!

FROZEN IN A CAKE OF ICE
TEXACO FLOWS FREELY

HERE'S a convincing "cold pour" test that anyone can make in the freezing compartment of a refrigerator! Frozen in a solid cake of ice, the new crack-proof Texaco still flows freely.

Watch the bubble rise as you turn the cake of ice from end to end. Many oils are dangerously sluggish in the cold—many harden thick as grease. Such oils bring needless winter wear.

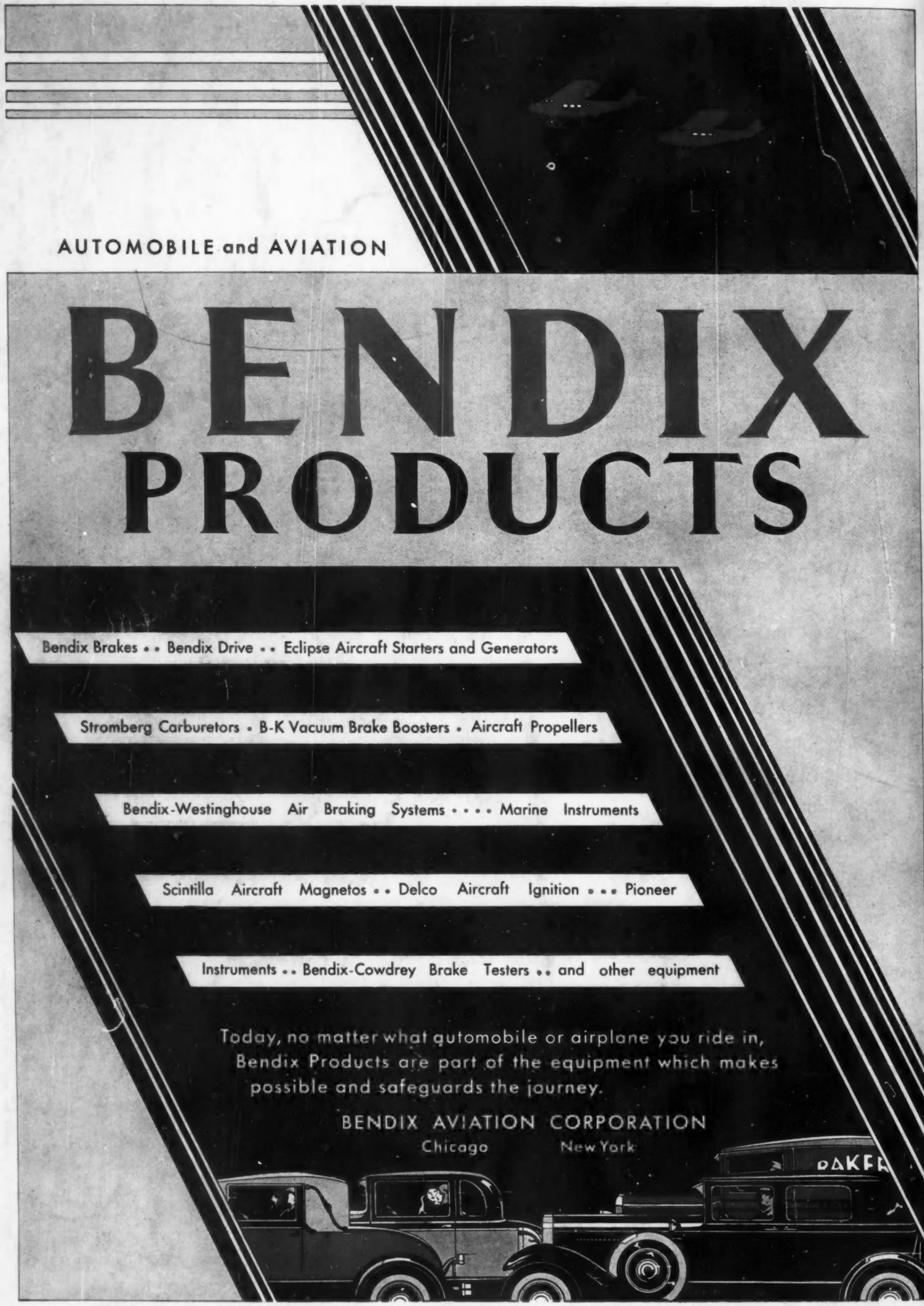
The new Texaco flows instantly. It lubricates even when water freezes! It is as free from objectionable carbon-forming impurities as from the cold-congealing substances that imperil an engine on frosty nights and mornings.

Drain out the old oil. Fill with the correct winter grade of the new crack-proof Texaco today.

THE TEXAS COMPANY, 135 E. 42nd St., New York

THE NEW TEXACO MOTOR OIL

"CRACK-PROOF" · · LONGER-LASTING


AUTOMOBILE and AVIATION
BENDIX
PRODUCTS
Bendix Brakes • • Bendix Drive • • Eclipse Aircraft Starters and Generators
Stromberg Carburetors • B-K Vacuum Brake Boosters • Aircraft Propellers
Bendix-Westinghouse Air Braking Systems • • • • Marine Instruments
Scintilla Aircraft Magnetos • • Delco Aircraft Ignition • • • Pioneer
Instruments • • Bendix-Cowdrey Brake Testers • • and other equipment
Today, no matter what automobile or airplane you ride in, Bendix Products are part of the equipment which makes possible and safeguards the journey.
BENDIX AVIATION CORPORATION
Chicago New York